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THE BOOMERANG AND HOW TO THROW IT.*

By Sir Ralph Payne-Gallwey, Bart.

In this short treatise I do not intend to discuss the boomerang from a scientific point of view, but merely to give my personal experience of it as a very curious and interesting weapon with a description of its construction and flight. The boomerang is a weird and erratic form of missile, and though I have about fifty, and have continually practised with them for many years, I have not one that, it may be said, closely resembles another in its behavior. It is impossible to reproduce with even approximate accuracy a good returning Australian boomerang, owing to the numerous twists and indentations contained in its outlines. These curious twists and hollows represent the experience of generations of native boomerang artists. Nor can we obtain any wood with a natural curve in its grain which is nearly as hard and heavy as that from which the boomerangs of Australia are fashioned. This hard wood allows the Australian to finish off his boomerang at its edges to almost the sharpness of a knife blade. As the material he employs is also very heavy, his weapon can be made so thin that it offers but slight resistance to the air when it is cast, while at the same time it has sufficient weight to give it the necessary momentum to travel a long distance. The only suitable wood with a natural curve that grows in northern latitudes is old and dry ash. If a boomerang has not the grain of its material running evenly from one end to the other it will soon fracture, though if made from naturally curved wood, the best of all, or even from wood that has been steamed and bent to shape, it may strike a road or a tree without being damaged. When a boomerang is constructed from a piece of wood that has been steamed to a curve, it is essential that it should be kept flat in a press or else between two boards with a weight upon them. If a boomerang of this kind falls on wet grass or is thrown in rain it is certain to lose its contour, and the slightest warp or twist will at once convert a first-rate weapon into a useless one, though the true cause of its deterioration may not be suspected. For this reason it should always be stored away perfectly flat when not in use, and, if necessary, retained in this state by means of pressure. Though the Australian returning boomerang has several twists in it and is never flat throughout its length, such twists are one and all purposely designed to assist the weapon in its flight. On the other hand, a casual twist or warp, caused by damp, has an opposite effect.

There are two distinct kinds of Australian boomerang—the one used in warfare and the returning one. As the latter is always more or less flat on one side it may easily be distinguished (A, Fig. 4). It will be noticed how slight is its curve (Fig. 1). If, however, we make one exactly similar as regards its size and curve it will make no attempt to return when thrown. Fig. 2 shows the above boomerang edgeways and emphasizes the lateral twists—rather resembling those of

* Country Life (London).

FIG. 1.—AUSTRALIAN RETURNING-BOOMERANG.

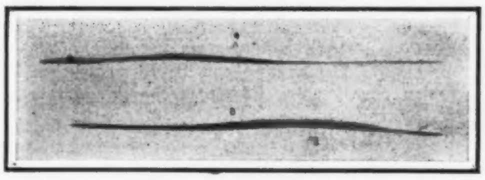


FIG. 2.—AUSTRALIAN RETURNING-BOOMERANG SHOWN EDGEWISE.

A. Its inside edge toward the spectator. B. Its outside edge toward him.

FIG. 6.—INCORRECT THROWING.

FIG. 7.—CORRECT THROWING.

FIG. 8.—CORRECT THROWING.

FIG. 12.—A GOOD RETURNING-BOOMERANG (ENGLISH).

FIG. 3.—AUSTRALIAN WAR BOOMERANG.

FIG. 9.—THREE RETURNING-BOOMERANGS THROWN TOGETHER.

FIG. 10.—CATCHING BOOMERANGS IN THE AIR AS THEY RETURN ONE BY ONE.

FIG. 11.—THROWING ONE BOOMERANG AT ANOTHER.

THE BOOMERANG AND HOW TO THROW IT.

the propeller of a steamship—which cause the weapon to return to the person who throws it.

The Australian war boomerang (Fig. 3) is nearly twice as large and heavy as the returning one, has no twists and is rounded on both sides. It does not return to the thrower. This weapon will travel, skimming low over the ground, to a range of from 150 yards to 180 yards, and the blow it gives a tree trunk at 100 yards is as if the latter were violently struck with a blunt and heavy sword. As an instrument of savage warfare it would have a terrible effect on a scantily-clad opponent. Though the returning boomerang (Fig. 1) was chiefly employed by natives for killing, as food, birds flying in small numbers or in flocks, it was also constantly used as an amusing plaything, just as a sling for pebbles or a bow and arrow might be carried by a schoolboy. All the best Australian boomerangs are closely notched on both surfaces. They are, in fact, roughly honeycombed all over, except on their edges. The notches are everywhere in contact, and run laterally along the surface of the wood. They appear as if they were scooped out with a tool like a quarter-inch gouge, though the little hollows thus formed are not deeper than the thickness of paper.

The Australian gave his boomerang this rough surface so that it might "bite" the air in its flight. For the same reason the outside or cover of a golf ball is indented or pitted, as when golf balls were made with a smooth china-like surface (as was formerly the case) it was found they would not fly far or accurately. There have been many diagrams in various periodicals describing the flight of a boomerang, none of which, in my opinion, has ever clearly indicated its career in the air. I will endeavor to elucidate this subject in a manner that I consider is easier to understand than one conveyed in a series of confusing lines and figures. For example, take up your position facing the north and throw your boomerang northeast. It should travel from right to left—the north being the far apex of its circular route—and return from the northwest. It should then pass close to you toward the southeast—for a score yards or more behind your back—and, returning again, spin down to the ground within a yard or two of your feet (Fig. 5). In this case the most favorable wind would be from the northwest. To put it shortly—throw the boomerang to your right front, or at an angle that is halfway between the point of your right shoulder and the direction you are facing, standing so that the wind blows toward your left front.

The simple diagram given in Fig. 5 shows the manner of throwing a boomerang as regards direction and wind, and the proper course of its flight. If thrown downward a boomerang will never return to the thrower. If thrown straight against the wind, especially a strong one, it will usually soar high in the air and come down edgeways with great force, almost perpendicularly and close to you—a most dangerous return if the sun happen to be in your eyes or in those of any friends near you. The perfect throw is the one in which the boomerang comes sailing back at a few feet above the ground, takes a dip just as it passes you—in which it almost scythes off the grass stalks—then rises and continues its flight for some 40 yards behind you, to return again and finally drop at your feet, spinning like a falling leaf or the winged pod of a sycamore tree. The best Australian boomerangs will now and then settle with such a slow butterfly-like flutter at the end of their flight that, when spinning but 4 yards or 5 yards above you, there is time before they reach the ground to look at your watch, count five seconds, and put it back again in your pocket!

In a strong wind a boomerang will never fly properly, as, though it may return past the thrower it will probably conclude its flight at 150 yards behind or to one side of him. A boomerang can be thrown a long distance if there is no wind, but will not return nearly so well as when there is a slight breeze to assist it to do so. If thrown downward it will travel still farther, but, of course, will not come back against the wind. The best throw I ever made downward was 270 yards. When throwing a boomerang, the great secret is to throw it with the wrist. The wrist can alone give the drawback snatch to its handle end which gives the weapon the rapid spin it should commence its flight with and without which it will never behave as it should do. The usual fault with the uninitiated is to throw a boomerang flatwise, as if casting a quoit or an oyster shell. This method is fatal to success and is shown in Fig. 6.

Figs. 7 and 8 show the position of the thrower when preparing to throw and just as the boomerang leaves his hand. In Fig. 7 the arm has been brought slowly forward, the wrist is in the act of propelling the boomerang and is at the same moment giving the drawback twitch to its handle which bestows the spin that gives life to the weapon, till it finally settles slowly to the ground, still spinning, at the end of its flight. This motion of the wrist, that imparts the spin to the boomerang, is identical with the pull-back of a cue at billiards when the player makes his ball return toward him by means of a screw stroke. Directly a boomerang ceases to spin or commences to spin slowly it falls to the ground like a wounded bird. The weapon should be thrown with the inside edge of its curve toward the ground as if cutting downward with a scimitar, its flat surface outward and its rounded one next you (Fig. 7). It should be aimed as if to strike the ground (which, of course, it will not do) at a spot some 30 yards to 40 yards distant from the thrower. The angle at which it should leave the hand, as before pointed out, should be halfway between the right shoulder and the direction the thrower is facing, i. e., to his right front, the wind blowing gently toward his left front, or in any event from his left side. The first two fingers and the thumb should alone grasp the handle.

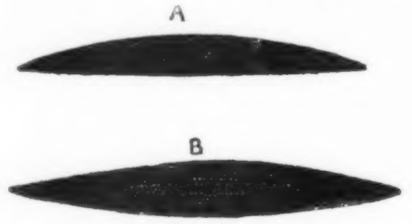


FIG. 4.—SECTIONS OF THE TWO AUSTRALIAN BOOMERANGS AT THEIR CENTER OF LENGTH.

A. The returning-boomerang. B. The war boomerang.

As the boomerang thrower becomes proficient he may indulge in many curious feats, though some of these require years of practice before success is attained. For instance, a boomerang can be thrown so as to ricochet along smooth ground like a flat stone over water, and after making three or four contacts return to the thrower—a pretty exhibition of skill. Again, several boomerangs can be thrown in rapid succession, each keeping its proper course and returning to the thrower, one after the other, like a number of birds wheeling to change their direction. I have even had a dozen spinning about me all clear of the ground at the same time, and all thrown by myself within eight or ten seconds. As a variety, three boomerangs may be held together in the hand and then thrown simultaneously as shown in Fig. 9, or, as in Fig. 10, three may be thrown round a tree, at intervals of two or three seconds, and caught in the air as they return one by one to the thrower, dropping gently to the ground as they spin over him. They should, of course, be taken at arm's length, as if allowed to descend near the face unpleasant consequences may result to the features.

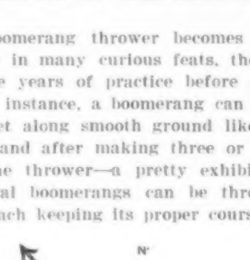
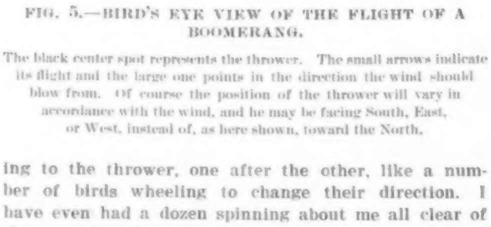


FIG. 5.—BIRD'S EYE VIEW OF THE FLIGHT OF A BOOMERANG.

The black center spot represents the thrower. The small arrows indicate its flight and the large one points in the direction the wind should blow from. Of course the position of the thrower will vary in accordance with the wind, and he may be facing South, East, or West, instead of, as here shown, toward the North.



EXAMPLES OF BOOMERANGS.

The four upper ones of the left hand column and the two upper ones of the right hand column are Australian returning boomerangs. The three center ones in the picture are Australian war boomerangs. The remainder are of English manufacture.

In Fig. 11 a boomerang has been cast round the large tree on the right of the picture, the distance of which from the thrower in a straight line is about 100 yards. As it comes into view from behind the tree it is being struck with another boomerang aimed to hit the one first thrown as it comes soaring back.

A curious use for a boomerang is to throw it over a covey of partridges, if they have alighted in a field of roots or other cover late in the season when the birds are wild and will not suffer approach with the gun. As the boomerang sweeps over them, and flies round about in a large circle like a hawk, the birds will squat close to the ground and can often be walked up within easy gunshot. Two or three small holes drilled in each of its ends causes the boomerang to emit a slight whistle or scream as it rushes through the air, which no doubt adds to the alarm of any birds it passes over.

Though the English imitation of the Australian weapon has not all the tricks and antics of the aboriginal one, yet if carefully shaped it will act quite well enough to cause great amusement and interest. The home-made boomerang always requires to be sharply curved, so that this curve may in some degree take the place of the non-understood twists and indentations of the genuine article. Fig. 12 shows an excellent form of returning boomerang made for me by Messrs. Buchanan, 15, Pall Mall, London, who keep a stock of them for sale. They are small and light and hence are not dangerous to use as often are the larger and heavier ones. They can easily be manipulated by a lady. This boomerang (Fig. 12) I evolutionized after several years of modeling, for a chip here, a shaving there, a trifle too little or too much curve, a quarter of an ounce in weight one way or the other or even too thick a coat of varnish, will make or mar one of these fanciful and fascinating playthings. Playthings it is indeed hardly correct to call them, as the flight of a boomerang is a scientific puzzle that is never likely to be solved, though many scientists have presented us with learned though usually divergent solutions.

NOTE.—Owing to their rapid spin and quick evolutions and their distance from the photographer, the boomerangs shown in the instantaneous views are naturally not very clear. No doubt they could have been touched up or even inserted if desired. In these photographs they are, however, left exactly as they appeared on the plates when the latter were developed and have not been altered or improved in any respect whatever.

THE INFLUENCE OF WATER ON BEER.

By ROBERT GRIMSHAW.

ALTHOUGH the principal materials used in brewing—malt, hops and water—are essentially the same in all localities, there is no doubt about it that beer brewed in various places, out of the same constituents, and by exactly the same process, differs widely in various properties, and especially in taste; and this is principally to be ascribed to the local water. In this particular, the steeping water used in swelling the grain in the malting process is of special importance in determining the character of the beer brewed from the malt. As an instance of this, says Prometheus, the St. Petersburg beer has a certain bitter after-taste, attributed to the water of the Neva, which is very soft, and contains but little lime. When, however, the Petersburg brewers employ English malt, the taste of their beer is greatly improved; and this is attributed to the influence of the hard English water used in malting. But the addition of gypsum (plaster of Paris) to the Neva water produces exactly the same result.

Following out this idea, suitable additions of the proper mineral substances to the water used in malting enables brewing very accurate imitations of porter by the production of a "London water." When, however, the Trent water is imitated, there may be brewed ale which is almost exactly like the genuine local product; and when the waters of the Beraum and the Isar are imitated and used in malting, Pilsener and Münchener beers are the result of proper treatment.

The higher the percentage of alkaline carbonates in the steeping water, the greater the aroma and sweetness of the beer produced, all other conditions being, of course, the same. The coloring matter and the bitter principles in the grain are neutralized by the alkaline carbonates; but the sweetness and "fullness" of taste of a beer is dependent on the presence or the absence of such bitter principle in the barley.

All the brewing waters used in the great breweries in München are different from each other in percentage of gypsum; but they have in common one characteristic—a relatively and absolutely high percentage of lime and magnesia carbonates, which give them all the München characteristics. The Bohemian malt and beer types owe their properties to the steeping water; which, while very soft, is not too soft. The Dortmund type of beer calls for its successful imitation the addition to the brewing water of considerable quantities of gypsum, and at the same time considerable lime. To make the Wien (Vienna) types of beer, the malting water must be softer and contain on the average less earthy carbonates than for the Münchener, but more than for the Dortmund type; there must, however, be more gypsum than for Münchener beer, but less than for the Dortmund kinds.

Thus the essential characteristics of a beer, no matter where brewed, depend in the first place on the nature of the water used in steeping the grain for malting, and only secondarily on the nature of that used in the brewing process itself.

THE GAS AND THE STEAM ENGINE.

THE CHIEF POINTS OF DIFFERENCE BETWEEN THEM.

BY WILLIAM H. BOOTH.

IN all matters pertaining to mechanical engineering there is always a tendency to follow a certain beaten track which has been traced out by a vehicle similar to the one we happen to be in. But this does not always lead to good results. As between the gas engine and its forerunner the steam engine, there are great points of difference, though in general appearance there may be nothing much to choose between them and their principle of action may be alike. Let one point alone be considered in this article. Let there be taken the shape of the indicator diagram of the steam engine. Let its general form be considered and the reasons for that form, and for the angle of any particular line and the physical facts which may influence such details, or the mechanical facts which render them necessary. We have all observed that the diagram of the gas engine is taken from it with a similar instrument and that the form of the diagram is almost identical with that of the steam engine diagram. In fact, we may learn that the gas engine diagram has been tinkered at until it has resembled in shape, as clearly as it could be made to do, the indicator diagram from the steam engine.

In order to fix our ideas let a brief *résumé* be made of the thermal and mechanical conditions of each of the heat engines, the steam and the gas engine. In the former case the working cylinder is, to use the word of Watt, maintained as hot as the steam which enters it. If it be not so maintained then it will proceed to attain the same temperature as nearly as it can do, by abstracting heat from the working fluid, from the steam within it, and much of this will be condensed as a result. Were we to admit steam somewhat later in the stroke no benefit would accrue in practice, and as we shall see later, in ordinary cases the mechanical action of the machine would be spoiled and turning moments rendered irregular. There might be set up shock and noise.

In a steam engine it is not usual to compress the residual steam in the cylinder up to the pressure in the boiler. When the piston reaches the end of the stroke and it becomes necessary to move it outward once more, it cannot be started moving except by a considerable force, such force being proportioned to the velocity, or rather to the square of the velocity, and only to be got out of either the flywheel through the medium of the crank-pin and other parts, or from steam pressure admitted behind the piston. If the flywheel be the moving power the forces in the connecting-rod are reversed and any slackness of parts is demonstrated by noise or knock.

With steam as the starting agent the lost motion of the working parts is gradually made good by compression and the steam is admitted directly upon the dead center and starts the piston on its forward path with no further shock, for all lost motion is taken up and pressure is continuously in one direction, so that reversal cannot occur.

Thus it is that the steam engine diagram has been evolved to its present form. The salient features are a vertical steam admission line, a horizontal line of sustained pressure up to the point of cutoff, an expansion curve, exhaust opening and a sustained exhaust line, followed by a more or less extended curve of compression ending in the first-named vertical line of steam admission. We might, of course, rely on a full compression of the residual steam to boiler pressure to start the piston in movement, and calculate on a late steam admission, if we believed it to be an economical advantage to do this. But the expansion of the compressed steam would follow the compression curve or even fall below it. It would be very steep and the pressure to urge forward the piston would quickly fall below a sufficient degree, and again there would be a mechanical knock. So that even if it were desirable from a heat-engine point of view to admit steam late, quite an appreciable time after the crank had passed the dead center, it would not be mechanically desirable.

This I state, fully aware of the fact that in the early days of higher pressures the old beam engines of Lancashire would not admit of steam admission dead upon the center in all cases. The reason of this was that the masonry foundations of these old beam engines were insufficiently heavy to hold down the engine after steam pressure in the boiler had been put up to 30 pounds for engines that were made to be worked with only 7 pounds boiler pressure. Sometimes the cylinder foundations would lift, at others it would be the wall which held up the entablature pillars, and yet again the wall under the crankshaft bearing. By allowing the steam admission to be gradual the maximum pressure on the piston could not be reached, for the big piston ran away from the capacity of the valve to admit steam quickly. The steam might have been admitted at the dead center, but it would be through a narrow notch lead and the main edge of the valve was too late to let in steam quickly behind the retreating piston. The trouble was variously surmounted in later years by hanging weights to the various foundation walls, bolting them to girders let into the main wall of the building, and later still by the use of a high-pressure cylinder between the beam center and the connecting rod. This cylinder counteracted the low-pressure cylinder stresses at the beam center-bearings and was also made to bear somewhat on the crankshaft wall. It also reduced the upward lift on the low-pressure cylinder wall by converting the low-pressure cylinder again into an atmospheric cylinder. But this by way of digression to explain an exception, which under the peculiar circumstances was allowable.

The modern steam diagram, then, has a rounded heel, a vertical admission line and a level steam line, and to this pattern it was attempted to bring the gas-engine diagram. It may very well be doubted if such practice is correct. The gas engine is not a steam engine. It is exposed to a working agent of so high a temperature that unless means be taken to moderate the effect of this, the cylinder and piston would become red-hot and would be unable any longer to work together.

In order to obviate this difficulty the cylinder, and in larger engines the piston also, is made with a water-jacket, thereby effectually guarding it against ever becoming, what was so desirable in the steam engine, as hot as the fluid that is within it. The gas engine has, in fact, a water-cooled cylinder and this water absorbs about a third of the heat of the fuel which enters it, or in some cases perhaps only a fourth. Thus at one unscientific blow the internal waste of heat in the gas engine is brought up to that of a very ordinary steam engine, in the cylinder of which some 15 to 50 per cent of the steam admitted is condensed during admission and more is often condensed after the admission valve is closed.

Now the gas engine always carries a high degree of compression. The contents of the cylinder are compressed up to a pressure sufficient to start the moving parts upon their next forward stroke and this compression starts early, and, even with no reinforcement, will carry the piston some way without the aid of the crank. But in an engine on the Otto cycle this action is omitted every second revolution, or during a non-explosive stroke, and the crank-pin has to pull forward the piston. This fact is a strong argument in favor of the two-cylinder tandem type of engine in which the compression strokes of the two cylinders not coinciding, one or other compression is always ready to push the moving parts and prevent or reduce knocking effects.

But given this high compression, the need for early explosion in a gas-engine cylinder no longer holds. The ignition may be made a bit later and the explosion line may lean forward, so that maximum pressure is attained after the crank has gone considerable angular distance past the dead point. The maximum stress does not act at the dead point, but at a time when the piston is moving rapidly and the gases are obviously still burning when the crank has gone thus far. Theoretically a delayed combustion is a wrong thing in a heat engine, all the heat of the working fluid of which should properly be applied at maximum temperature. But practice and the inevitable conditions of practice compel many modifications from theoretical perfection. When the engine is on its dead point the crankshaft is rotating at full speed, as usual. When the cylinder contains its minimum pressure at that point the piston is pressing the shaft upon its bearings with maximum intensity, and full braking effect is being generated at the bearings, but no work is being usefully performed, for the piston can do no useful work when not moving, though it can put on a braking effect by causing heavy pressure on the large rotatory piece. Thus while the piston is at rest, there is a heavy pressure of hot gas in the cylinder rapidly giving up heat to the water-jacket, so that much less heat is available to do work.

Suppose, however, that the crankshaft be allowed to rotate fairly free from frictional loading, past the dead point, and ignition is started slowly and delayed so that maximum pressure occurs behind a rapidly-moving piston, then will the heat generated be directly converted into useful work upon a crank at something like a useful angle and capable of work and moving fast.

There is a comparatively short period of exposure to the high temperature of the cylinder surface, whereas with early ignition and high vertical-explosion line the high-temperature gas is standing still idle between two virtually stationary pieces of cold metal, the cylinder end and the piston face, and much heat is then absorbed which under faster movement would go directly to work. Here then we see the difference between the steam engine and the gas engine, as regards the cylinders. One must be kept hot for economy, the other must be kept cool for safety. Let it not be forgotten that the gas-engine cylinder is not cooled in order that it may cool the working gas within it, but in order that its own inner surface may not become too hot for the piston to run on it, or too hot to allow of compression of the charge within it to a desirable degree. If too hot the cylinder would ignite a heavily compressed and therefore self-heated charge, and all gas-engine experts know that some trifling projection, such as a bolt head, will serve to cause premature explosion, because from its projecting length it cannot be kept cool by the jacket and it becomes an igniter, so that an engine will run without any intentional ignition. In fact, the Diesel engine does so, for its compression is so high that the charge would ignite too early every stroke, so that Diesel avoids this by delaying the charge of fuel until he wants the heat. He then sprays the fuel into compressed air hot enough to ignite the spray and he maintains the fuel spray for some time behind the retreating piston, and the heat thus generated goes at once into work and the loss to the jacket is comparatively small; while the efficiency is high, very largely because of the reduced cooling effect of the water-jacket on the working gases, which are only burned behind a moving piston and generate turning effort directly, when otherwise, with early maximum pressure and full instantaneous explosion, they would be wastefully expended, however correctly used in a narrow theoretical sense. We cannot reason out these things theoretically, and must conform practice to events we cannot control and the necessity of a cold cylinder is one which is, so far, beyond our powers to remedy.

It is clear from the foregoing considerations that the gas engine cannot be worked like the steam engine. The steam engine is a little better machine, theoretically, because it is a machine to be worked nearer to its working fluid temperature, but it is a less efficient machine than the gas engine in practice, because what the gas engine throws away in its jacket is thrown into the condenser of the steam engine, while the gas-engine furnace only sends away its wastes through the engine, so that the engine exhaust and the furnace exhaust of the steam boiler are reduced to one loss in the gas engine. Then despite the cold cylinder, the working fluid in the gas engine works between a greater range of temperature than does the steam engine, and this renders possible a better efficiency apart from the fact that one uses fuel in its cylinder, the other uses fuel in an outer vessel at atmospheric pressure, and has heat-transfer wastes to the water. The steam engine is less direct, but we should not forget that the gas used in the gas engine only contains a portion of the calorific power of the fuel, and that any attempt to increase the percentage of calorific utilization results in difficulties with regard to compression that may render such attempts undesirable in large engines. But these matters properly belong to another article. In this an attempt has been made to show that it is not correct to regard the gas engine as an exact mechanical and thermal parallel with the steam engine, because they differ fundamentally in the essentials of practice, as far as the treatment of the cylinder in regard to its effect on the working fluid, the effect of the working fluid on the cylinder, and the influence of their essentials of design are concerned, for in all engineering the best economy is a matter of much compromise of warring elements, and this is perhaps more the case with the gas engine than with the steam engine.—Power.

The greatest daily change of temperature to be found on the earth's surface is in Arizona. There is frequently a change of 80 deg. in twelve hours.

ELEMENTS OF ELECTRICAL ENGINEERING.—XX.

ALTERNATING CURRENT MEASURING INSTRUMENTS—RECORDING WATTMETERS.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1693, page 374.

IN clear distinction from the classes of galvanometers or measuring instruments in which there is a suspended magnet or a suspended coil is a sort in which there is no permanent magnet at all, nor even any iron. At least two coils are involved, one fixed and the other movable; by the passage of currents through these, magnetic lines of force are set up in

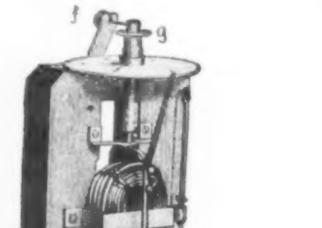


Fig. 99.—Siemens Electro-Dynamometer.

the air and the one coil tries to turn so as to let its field merge with that of the other. The absence of iron removes errors due to hysteresis, eddy currents and variation of permeability, so that no hindrance is presented to the accurate measurement of alternating currents.

The defect is present, however, and irremediable, that for weak currents, the field magnetism set up is so weak as to make the first part of the scale useless.

Weber seems to have been the first to construct instruments on this principle, and, to emphasize the absence of a permanent magnet, he called the new sort "electro-dynamometers." His particular arrangement will be referred to under the topic of wattmeters. A simple construction adapted for measuring reasonably strong currents—therefore being really a sort of ammeter—was devised by Siemens, and is now commonly referred to as the Siemens dynamometer. Though not conveniently a portable instrument, this style has great value in being simple, highly accurate, and quite independent of wave forms and frequency of the alternating current. With various modifications and refinements it is still the type of ultimate reference for

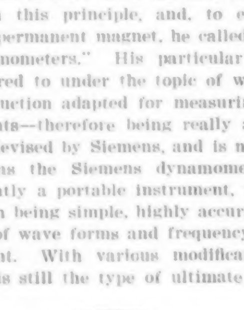


Fig. 100.—Diagram of the Siemens Electro-Dynamometer.

calibrating the more commonly used instruments.

An outside view of the form as actually made by Siemens is given in Fig. 99, and a diagram of the connections in Fig. 100. The instrument is really double, for it has two stationary coils of different sizes of wire and number of turns, whereby a great range of small and large currents may be measured. In a familiar case, one coil, marked *c*, is made from No. 10 wire, wound around a central wooden block about three-quarter inch by two inches in twelve turns per layer and five layers. Over this coil is another, *d*, of No. 4 wire, of only four turns. With the former coil in circuit, currents up to 15 amperes can be read, and with the other up to 25 or more. The large wire coil starts at binding post 1, and the smaller at 2; their other ends are joined together at *e*, and to mercury in a cup in the wooden cross bar. A single loop, *b*, of No. 6 copper wire, embraces both these fixed coils, its ends dipping into mercury cups, one in the cross bar just mentioned, the other in the base. This latter cup is connected to the middle binding post 3. This loop is suspended by a silk or linen thread extending through a slender spiral spring and wound around a tiny windlass, with a thumb knob at *f*; by this means the coil may be readily lowered when not in use, and thus lessen the danger of breaking the suspending thread. Attached to this movable loop is a pointer that is limited in its swing to the distance between two stops, *a* and *a'*, fastened to the edge of a fixed brass circle divided into degrees. One end of the slender spring referred to is attached to the loop, while the other end is fastened to a thumb-piece *g*, called a torsion-head, free to turn in the center of the graduated disk. To this center-piece a second pointer is attached, almost reaching to the first.

With this detailed explanation of the mechanical construction, the action and method of using the instrument will be more readily perceived. With no current flowing, the instrument is leveled, and the two pointers made to coincide with the zero of the scale. Since the pointer on *g* is adjustable, this coincidence is easily effected. Now if one wire from the circuit in which the current is to be measured is brought to 2, and the other to 1 or 3, current will pass in series through one of the fixed coils and the movable loop. The arrows indicate directions that may prevail at a given instant. The movable loop will try to place itself parallel to the coils, and with the connections shown, it will move in the direction of the arrow at the end of its pointer, but can go no further than the stop *a'*. The thumb-piece *g* is then turned in the opposite direction, as indicated by the arrow at the end of its pointer, thereby putting a twist into the spring, but at some particular point the torsion on spring will just balance the torque due to the current, and the pointer on the loop will again be restored to the zero position. The number of degrees through which the pointer has had to be turned will be proportioned to the *square* of the current. The square root of the number of degrees of each particular reading must therefore be extracted, and to be translated into amperes, this root must be multiplied by the "constant" for the particular instrument. In this respect some similarity to the case of the tangent galvanometer will be recognized. That the torque varies as the square and not as the first power of the current can be seen by the fact that doubling the current doubles the field of force of both members of the instrument, and the resulting force is then four times as much as before. Were the current in one member kept constant while that in the other was varied, the torque would really follow the simple law, and this is the case of the Weston instruments, in which the permanent magnet contributes a constant field strength, while the current in the little movable coil alone varies.

The "constant" must be determined for each particular instrument, and in comparison with some other taken as standard. A common value for the size of dynamometer just described is about 0.8 for the inner coil and 2.4 for the outer.

As an example of the application of the instrument, suppose with a given current a balance was found when the deflection was 115 deg., the inner coil being the one in circuit. The square root of this number is 10.7; if the constant is 0.8, the product becomes 8.56, meaning that number of amperes. If the degrees were 315, the current would be 14.2 amperes. If a complete turn of the thumb-piece was insufficient to restore the loop to the zero position, the circuit wire

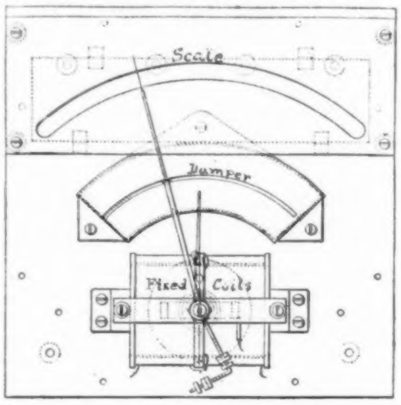


Fig. 101.—"Keystone" Voltmeter for Alternating Currents.

should be transferred from binding post 2 to 1. Suppose then a twist of 100 deg. sufficed. Extracting the square root and multiplying by the other constant, say 2.4, the number of amperes is found to be 24.

To make accurate readings, about the same precautions need to be observed as with a tangent galvanometer. Especially must the presence of external fields between conducting wires be eliminated by twisting the two together, as in the manner of ordinary lamp cord. With one of these instruments at hand, a person would have accurate means of calibrating the more portable of the switchboard types of instruments. Though usually limited to use with alternating currents, these dynamometers are equally accurate on direct currents, and the constant can even be determined with that sort and still be regularly used for alternating. It is always well to take the precaution to place the instrument so that the plane of the loop is east and west, and when using direct currents to eliminate errors due to the earth's field by reversing direction of current and taking average of the two values.

Voltmeters can be made on the same principle, but using fine wire coils and further putting a large resistance in series with them. A more practical and direct reading instrument, though not having equal divisions, is commonly made, imitating the appearance and construction of the Weston direct current voltmeters. Of course a permanent magnet is inappropriate, but its place is taken by a pair of fine wire coils, the inside diameter being not much over an inch. The movable coil, to which the pointer is attached, is pivoted between these, and is acted upon by the electro-magnetic field set up by the current in the fixed coils. The movable coil cannot, however, be wound upon a metal frame, as in the case of the direct current instruments, for in the presence of an alternating field magnetism, short circuit currents would continually flow in such a closed conductor, and produce disastrous heat and a waste of energy. This little

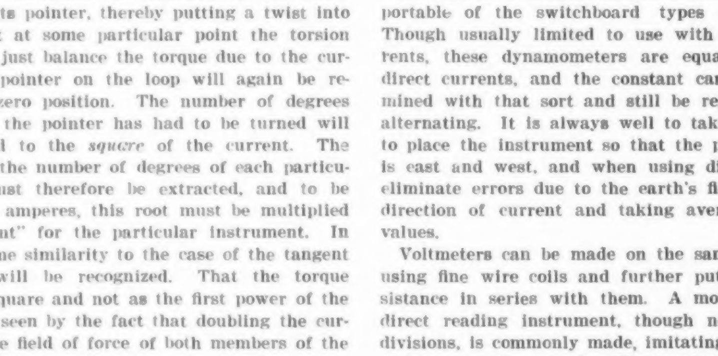


Fig. 102.—"Keystone" Voltmeter, Longitudinal Section.

coil is wound with a sufficient number of turns and layers, so that when impregnated with varnish and dried, it possesses a surprising amount of stiffness, and can in itself receive the trunnions, or pivots for supporting it in its jeweled bearings. Hair springs can be fitted to these pivots, and serve both to conduct the current and to give the mechanical reaction as usual. The movable system can be made to weigh only a few grammes, but even this slight weight will produce some

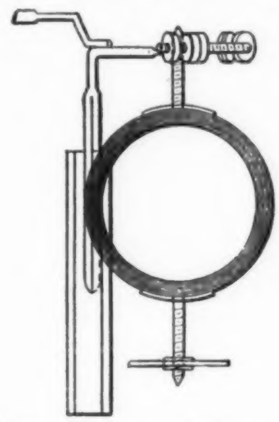


Fig. 103.—Movable Coil for "Keystone" Voltmeter.

considerable swinging, and so a substitute is sometimes sought in air damping, by means of an aluminium or mica vane attached to the pointer and swinging in a circular trough.

The Weston Company makes a large variety of this class of instruments, but no fundamental patents are in existence, and the market is free for all. The exact construction of a laboratory pattern of the "Keystone" voltmeter is given in Fig. 101, showing the plan; Fig. 102, showing the longitudinal section, and Fig. 103, showing the movable coil. In the plan, the fixed coils are represented as clamped together, with only enough opening in the flanges to give egress to the pivots. Inside diameter of the coils is shown by the parallel dotted lines, and the position of the movable coil itself just below the cross bar that carries the jeweled supports. The opening in the annular trough is seen midway between the coils and scale at end of pointer. The shape of the various parts is still further seen in the sectional view, but a peculiarity in this particular make will be noticed in the substitution of a loop spring for the upper spiral one. This is claimed to afford some help in providing more equal divisions on the scale. The simplicity of shape of the movable coil is clearly brought out in Fig. 103, which shows also a part of the counterweight, and a very oblique view of the air damper. Though made thus with delicate workmanship, these instruments require much more energy to operate them than those of the permanent magnet sort; they are not dead-beat, nor free from influence of exterior magnetic fields. An instrument for 150 volts may have a resistance of 500 or more ohms in its fixed coils, 100 or more in its movable one, and be put in series with several thousand ohms externally, but this is far less than is possible with the other kind. Whatever external resistance is used must be of the "non-inductive" arrangement; if in spools, the coils must be looped in the middle, and thus terminating with both ends on the outside layer, or wound on cards and pressed flat in bottom of case. In spite of the fact that a very large number of turns are used in the operative part of instrument, and self-induction varies as the square of the number, the actual value of that factor, due to the relatively small current and the absence of iron, is very small. The act of including the large non-inductive resistance so reduces the angle of lag that the voltmeter as calibrated for alter-

requirements of a wattmeter. A field of force is set up proportional to the main current, and the current driven through the shunt is proportional to the voltage. A torque results proportional to the product of these two factors, and this product represents the watts. A further extension of this sort of instrument will be discussed under the head of recording meters.

Voltmeters for very high-tension alternating currents are not often connected directly to the service wires. Too great and unnecessary personal danger would be involved, so the simple means of transforming a high voltage to a conveniently low one is made use of. "Potential" transformers insulated with all the care desired, are put across the main circuit, so that a secondary current only is led to the instrument. Although the scale purports to show the full voltage, the facts are that a low one, proportional to the main, is really the active one. Likewise, in the case of the ammeter, just the same objection to the high potential being brought to the front of the switchboard still holds, so "current" transformers are put in series at a safe point, and a low voltage current, proportional to the main current, arrives at the indicating part of instrument.

Shunts, such as are successfully used with direct currents, are not appropriate for alternating currents. Errors due to inductance in the shunts or in the movable coils themselves interfere with the accuracy of the readings, and happily, the use of the little transformers just mentioned solves the question of measuring large currents in a much more satisfactory manner.

Some alternating current instruments have iron within their coils, and are useful where a high degree of accuracy is not essential. One of the best examples of this construction is the Thomson "inclined-coil" type. A sectional view of the ammeter is given in Fig. 104. A coil of coarse wire, *A*, is fastened in a position at an angle of 45 deg. with the base, and tipping directly toward the scale; a vertical spindle of

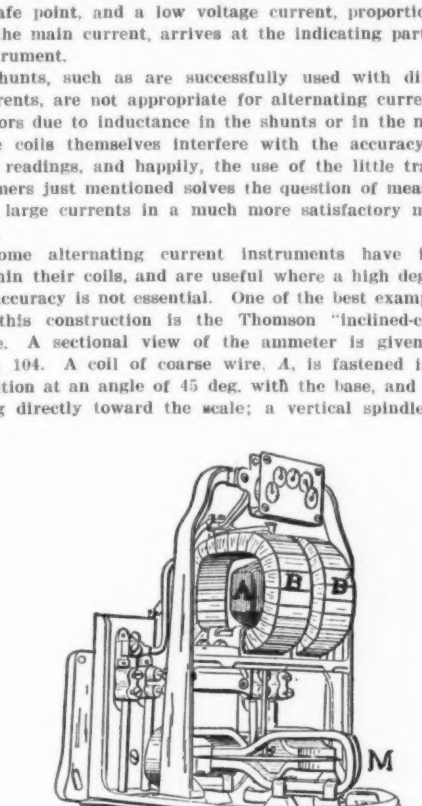


Fig. 105.—Thomson Recording Wattmeter.

non-magnetic material extends through the opening in the coil, and terminates in steel points resting in jeweled bearings; on this spindle and at the center of coil is a piece of soft iron, *a*, itself fixed at an angle of 45 deg.; a pointer, *b*, is attached in the ordinary manner, and a single spiral spring, *s*, serves to give the mechanical reaction.

When current flows in the coil, lines of force are set up, and the bit of iron tries to set itself along the direction of these lines. To accomplish this considerable rotation is necessary, and the result is a surprisingly long range of movement of the pointer. Such a construction, however, is not free from errors due to

tions of the electro-dynamometer principle is in the construction of recording wattmeters. Not a little of the popularity of electric lights and power has been due to the accuracy with which a customer's supply can be measured. Added to the accuracy of the meters is their moderate cost and their freedom from climatic or other external influences.

The most common form of the meter, and readily recognizable from its adoption of familiar parts, is that of Prof. Thomson. A perspective view of one is

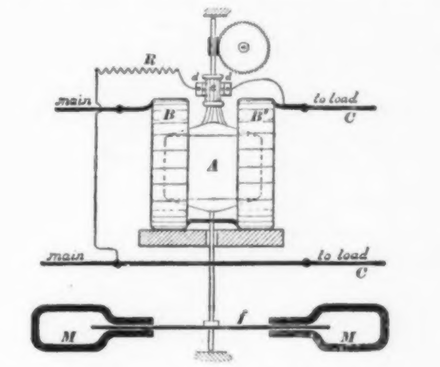


Fig. 106.—Diagrammatic View of Thomson Wattmeter.

given in Fig. 105, and a diagrammatic yet somewhat constructional view in Fig. 106. Two fixed coils, *B-B'*, are wound of coarse wire and connected in the main circuit; a hollow frame of paper is wound with fine wire, like any drum armature, and has its various loops attached to a tiny commutator, *c*, having silver segments; the brushes, *d*, are silver tipped. This armature is seen at *A* between the fixed coils. Its shaft is supported on jeweled bearings, and carries a worm at the top for actuating the train of indicating wheels,

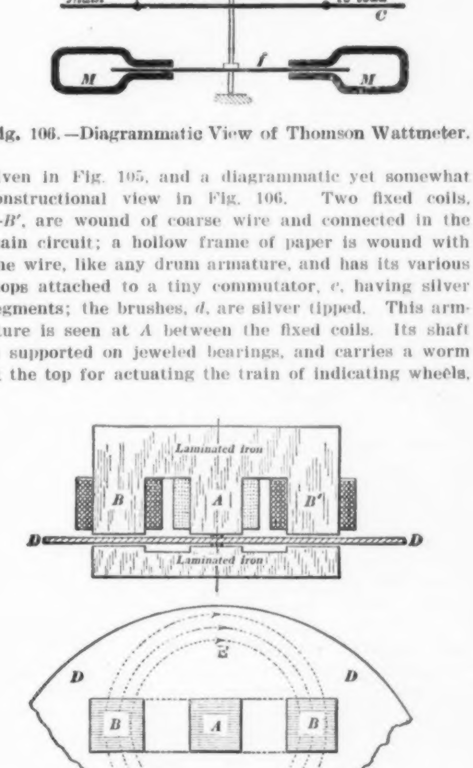


Fig. 107.—Disk and Magnet for Induction Wattmeter.

and at the bottom a copper disk, *f*, that is closely embraced by three retarding permanent magnets, *M*. In series with the armature winding is an external non-inductive resistance, *R*, experimentally determined for each instrument, and usually also a small coil of wire, in this same circuit, is placed within the field coil; the function of this latter is to give a small torque to neutralize the friction of the pivots and brushes. It is seen that the combination gives a torque proportional to the load, and the dragging action of the permanent magnets in producing eddy currents in the disks holds the speed proportional to the torque.

Some appreciable energy is consumed in the operation of such meters, for the shunt coil and winding represent a continual leak, and that of course a customer eventually pays for in the established rates.

Another form of recording meter that has lately come into prominence, due not so much to its accuracy as to its cheapness, is dependent upon the principle of the induction motor, and is commonly denoted as the "induction" meter. Differing from the other type, it has iron in its magnetic circuit, therefore introducing errors due to hysteresis and change of permeability under differing degrees of magnetic flux. At best the driving torque is very feeble, so the disk is made small and of aluminium, and in the entire absence of friction of brushes the disk actually rotates at a speed proportional to the load. The principle is that eddy currents are induced in the disk by the alternating flux of the fixed electromagnets, and at a time just right to be acted upon by a second flux from another part of the magnetic system, and thus produce an actual torque. The explanation is attended with some difficulty, and involves some of the most fundamental phenomena of transformer action.

The actual arrangement of the parts can be gathered from reference to Fig. 107. In the elevation is seen a stack of sheet iron, in the shape of a letter E, with

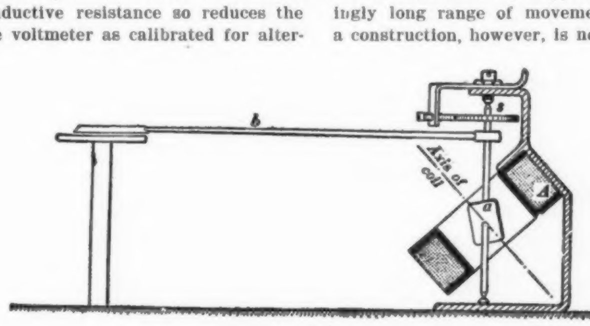


Fig. 104.—Thomson Inclined-Coil Alternating Current Ammeter.

nating currents is correct within a fraction of a per cent for direct currents.

A further modification of the dynamometer, and indeed, Weber's earliest application, is to make the stationary coils of coarse wire, and thus allow for putting them directly in the main circuit. The movable coil is still in series with a high resistance and connected directly across the circuit, as is customary with a voltmeter. The combination is thus seen to give all the

variations of wave form and frequency. The voltmeter made in this manner is especially affected by these causes, and recourse has been taken to the use of an obliquely-pivoted fine wire coil with double hair springs for the electrical circuit, as in the case of the dynamometer type. Wattmeters are also made on the inclined coil principle, the fixed coil being of coarse and the movable of fine wire as before.

One of the most interesting and practical applica-

poles at B, A, and B'; another stack is close to these poles, and in the narrow crevasse between them the disk revolves.

Pole A is wound with fine wire, and while it has a high self-induction in itself, it is put in series with sufficient other inductive winding so as to be connected without danger, or much loss, directly across the mains. Therefore a current flows through this winding proportional to the voltage of the supply circuit. Further, in consequence of the highly inductive character of this circuit, its current lags approximately 90 deg. behind the phase of the volts. A flux of lines of force through A induces eddy currents in the disk, at a given instant being represented by circles E, and by the principles of induction the maximum value of these eddy currents lags 90 deg. behind the current in this coil. The poles B and B' are wound with a few turns only of coarse wire and included directly in the main circuit; in consequence of the fewness of these turns there is only a very small lag of its current. There is therefore a flux of lines of force through these poles just in time to experience the eddy currents in the disk, and, by the principles illustrated in Figs. 29 and 30 of chapter VII, to exert on the metal that conveys them a rotative torque. Likewise the flux through poles B and B' produces eddy currents that could be represented by circles drawn around the poles as centers, and flowing under pole A at just the right time to be acted upon by the flux emanating from that pole. In case there is inductance in the load measured by such a meter, the currents in coils B and B' will lag to such an extent as to diminish the effectiveness of the torque, and the disk will properly rotate slower. If the current lags in the main circuit by nearly 90 deg., there will be almost entire absence of current in the disk when there is flux from the poles, and consequently no rotation will be possible. In regular operation there is a "dragging" permanent magnet on the other side of the spindle for producing eddy currents of its own, and retarding the rotation just as in the case of the motor-meter.

The induction meter will run on alternating currents only, while the other sort is equally adapted for both direct and alternating.

In the most recent types of motor meters attempts have been made to increase the accuracy and sensitiveness by reducing the friction losses; the armature coils are wound open instead of being upon a paper core, and, imitating the historic Thomson-Houston arc dynamo, are made circular in shape. Minimum weight and good ventilation are thereby secured, and by making the commutator only one-tenth of an inch instead of a quarter in diameter, the friction of brushes is diminished. The segments of the commutator are merely stuck to the spindle with very adhesive varnish.

ELECTRICITY AND MATTER.*

A DISCUSSION OF THE MODERN THEORIES.

BY MADAME CURIE.

Concluded from Supplement No. 1694, page 400.

THUS we see why it is that gases may become conductors under the influence of certain radiations, or of the combustion of flames. It has been known for a long time, however, that without any of these influences a gas cannot prevent the passage of electricity when the field is sufficiently strong. The phenomena of the disruptive discharge, including the spark, the arc, and the brush discharges, have long been known, and they take various and complicated forms in the air at different pressures; but until recently they have been very little understood. The theory of gaseous ions has thrown a new light upon this manner of discharge. As a result of recent researches, the disruptive discharges can be explained by assuming that the ions which have acquired a sufficient velocity under the action of an electric field are able to act as projectiles, which, coming in contact with the molecules of gas, ionize them by the shock which they produce. Negative ions are much more active ionizing agents than the positive ions, and can produce these effects in more feeble fields. It may be conceived, then, that the ions being multiplied by the shock of those already present, the conductibility of the gas becomes very great when the field is sufficiently strong, and the ionized gas is then luminous.

The cathode rays, which are produced when the discharge is made to pass in a tube containing a gas under low pressure, are the electrons sent off by the cathode with a great velocity. Since these electrons and the positive ions have different properties, the discharge tube takes on the well-known dis-symmetrical appearance, which the theory of the ions readily explains, but for which no oth - interpretation has sufficed.

The Roentgen rays, which are emitted from a Crookes tube, are believed to be in reality electromagnetic waves whose wave length is very short. Such waves as these are supposed to be emitted by an electron whenever it is subjected to an abrupt acceleration, such as is produced, for example, when the electrons of a metal are put in vibration by the impact of cathode rays.

In accordance with what has been said, all gases which show themselves conducting contain the charged centers which we call gaseous ions. The presence of these charged centers may be made evident by means of a very curious experiment, which utilizes the property which ions have of promoting the condensation of supersaturated water vapor. When the volume of a certain mass of saturated water vapor is quickly increased the vapor condenses to the extent to which it is supersaturated, but if the supersaturation is not very great, and if the vessel contains no dust, there is no noticeable condensation at the moment of change, and the gas remains transparent; but when the gas contains ions the condensation takes place readily—that is to say, with a smaller expansion. It is easy to regulate the expansion so that there will be no condensation when the gas is not ionized but an abundant condensation if ionized. In the latter case the condensation manifests itself by the formation of an opaque cloud which fills the receptacle. Investigation of this phenomenon has shown that the globules of water, which constitute the cloud, form themselves upon the ions, each of which serves as a center for one of them. Ingenious experiments have made it possible to count the globules present in a cubic centimeter of cloud and thus to obtain the number of ions present in this volume. By measuring, in addition, the total charge of the ions of each sign in a cubic centimeter the individual charge of the ions is determined—that is to say, the charge of a single atom of electricity. This charge is equal to 3.4 times 10^{-10} electrostatic units. In order to show this phenomenon the gas may be ionized by the introduction of a glowing platinum wire, and it will be recognized that there is an energetic ionization of the gas surrounding the incandescent body.

We will now pass to the essential facts revealed by the study of radio-active substances, and examine them from the point of view of the hypothesis of the atomic transformation of matter. Among the radioactive elements, some appear to be permanently active (uranium, thorium, radium, actinium) while others lose their radioactivity little by little (polonium). The most powerful representative of the permanently radioactive substances is radium. According to the theory of transformation this substance cha ıges very slowly, so that a given mass of radium would lose half its weight only in several thousand years. Consequently the quantity of radium which disappears from a gramme of this substance in an hour is absolutely inaccessible to experiments. However, a gramme of radium disengages each hour about 100 calories of heat. To conceive how enormous this disengagement of heat is, we remark that during the life attributable to radium the complete transformation of a gramme of this substance would produce as much heat as the combustion of a ton of coal. The transformation of radium, then, if transformation there be, is not to be regarded as an ordinary chemical reaction, for the quantity of heat involved is of a far higher order. One is led to conceive, rather, that the atoms themselves are transformed, for the quantities of energy put in play in the formation of atoms are probably considerable.

Indeed, the phenomena of radioactivity has a palpably atomic character, which was brought to light in the beginning of researches on the subject. It was precisely the absolute conviction that we were dealing with an atomic phenomenon which led M. Curie and me to the discovery of radium. If the radioactivity can not be separated from the atom it is very difficult to conceive anything but the atom itself involved in the transformation.

The effects produced by radium are very powerful considering how small is the quantity of this substance at disposal for experiments. There is a spontaneous and continuous emission of rays, analogous to those which we know are produced by means of an induction coil in a Crookes tube, and these rays produce ionization of gas in the same manner. They are able, for example, to produce the rapid discharge of an electroscope. The energy of the rays is so great that the discharge is produced even across a thick metallic screen, for the rays can traverse such a screen.

Some of the rays comprise electrified particles moving with very great velocity. Some are charged positively, and their dimensions are comparable with those of atoms; while others are negative electrons, whose electric charge may be shown by direct experiments. Admitting that all these projectiles come from the atoms of radium themselves, it is difficult to avoid the conclusion that the departure of a positive particle must necessarily cause a modification of the atom which expels it.

Among the electrons emitted there are some whose velocity is enormous, and is in fact no less than nine-tenths the velocity of light. It has been found that the mass of these projectiles (which are the most rapid that we know of) is greater than that of slower-moving electrons, and this result may be considered as a confirmation of the theory according to which the mass of an electron is regarded as the result of electromagnetic phenomena.

The energy of the rays of radium is also manifested by their capacity for exciting the luminosity of various phosphorescent substances. Radium salts are, indeed, themselves luminous, and the light is readily visible in certain conditions.

Here are now a new series of facts which are interpreted by the theory of radio-active transformation. Radium disengages continuously a substance which behaves like a gaseous radio-active material and which has received the name of *the emanation*. Air which has been in contact with a solution of radium salts is charged with the emanation, and may be drawn away and studied. Air containing the emanation is strongly conducting. A sealed glass tube in which the emanation has been imprisoned acts on the outside like a radioactive substance, and is able, for example, to discharge an electroscope. When the emanation is drawn into a flask containing zinc sulphide, the latter becomes luminous. The emanation is an unstable gas and spontaneously disappears, even from a sealed glass tube, at a rate in accord with a strict law, by which a given quantity of emanation diminishes by half in about four days. The emanation possesses the property of imparting radioactivity to all the bodies in contact with it, and such bodies are said to possess induced radioactivity.

In the theory of atomic transformation the emanation of radium is the first product of disintegration and is transformed in its turn. The induced radioactivity to which it gives rise is considered as due to a solid radioactive material, which results from the transformatio.. of the radium emanation. Three different radioactive materials are distinguished in the induced radioactivity, which constitute three successive terms of the transformation. Each transformation is also accompanied by the emission of rays, and the expelled particles are also counted among the resulting products.

Induced radioactivity does not disappear completely; but there remains after the lapse of a day a very feeble residue which persists in part for years, and which is believed to be adding new terms to the series of successive transformations.

A new fact of great interest has come to the support of the theory of the transmutation of radioactive substances, and has, indeed, made it almost indispensable. It has been proved that radium, a perfectly definite chemical element, produces continually another perfectly definite chemical elemen* helium (Ramsay and Soddy). It is admitted that helium is one of the products of the disintegration of the atom of radium, and it is noteworthy that helium occurs in all the radium-bearing minerals.

The theory of the radioactive transformation has been extended to all the radioactive bodies, and investigations have been made to determine if the radioactive substances heretofore considered as elements

* Abstracted from a lecture. Translated, by permission, from Revue Scientifique, Paris. Fifth series, Nos. 20, 21, Vol. vi., November 17 and 24, 1906.

are not to be derived from one another. The origin of radium itself has been sought in uranium. It is well known that radium is found in the uranium-bearing minerals, and it appears from recent researches that the proportion between the quantities of radium and uranium is the same in all these minerals. Uranium may, then, be thought of as a mother substance, which disintegrates with extreme slowness, giving place to the production of radium and the products which succeed it. It appears also to be probable that the last term of the radioactive series is polonium. It may be recalled that uranium was the substance in which the property of radioactivity was discovered by M. Becquerel, and polonium is the first new substance which was discovered by the aid of radioactivity.

A series of analogous considerations has been established for another radioactive substance—thorium. In this case thorium as a primary substance generates radio-thorium, a substance recently discovered, which gives rise to the gaseous radioactive emanation of thorium and various products of radioactivity induced by this emanation. Actinium also gives place to a series of transformations similar to those of thorium, and it, like radium, produces helium.

All the radioactive substances which have been studied sufficiently from the point of view of their disintegration follow a law of decreasing progression, characterized by a constant coefficient. This coefficient may be defined as the time required for the diminution of the activity by half. These constants appear to be independent of the conditions of experiment, are characteristic of the substance to which they appertain, and seem to be capable of fixing an absolute scale of time. Thus the emanation of radium diminishes by half in about four days, while that of thorium diminishes by half in about one minute, and that of actinium in about four seconds.

I have already stated that the radioactivity is a general property of matter. If the theory of radioactive transformation continues to inspire a growing degree of confidence, it will result in an important consequence for geology, and will lead to a careful study of the proportions of the elements occurring in rocks, with a view to deduce their relative ages.

It is plain that the hypothesis of radioactive transformation is well adapted to the present state of the science of radioactivity. It was among those proposed by M. Curie and myself at the beginning of our researches on radioactivity; but it has received its precise development by Rutherford and Soddy, to whom it is for this reason generally attributed. It seems to me, however, better not to leave the domain of demonstrated facts, and not to lose sight of other explanations of radioactivity which have been proposed. The actual state of the science does not seem to me far enough advanced to warrant a positive conclusion.

In closing, the general importance of the phenomena of radioactivity may be recalled. For physics the radioactive substances constitute a new implement of research in consequence of the rays they emit, and they have actively contributed to the development of the theory of the conduction of gas and of the nature of the electron. By their numerous chemical and physiological effects, and their possible influence on meteorology, these substances extend their sphere of action in the domain of all the science of nature; and it is probable that their importance for the development of science will go on increasing. Finally, it has been shown that there is nothing absurd in supposing that the energy we receive from the sun may be in part, or even in total, due to the presence of radioactive bodies which it may contain.

THE SIXTH SENSE OF FISHES.

THE TRUE FUNCTION OF THE LATERAL ORGANS.

BY N. SCHILLER-TIETZ.

The bodies of fishes are marked on each side by a line called the lateral line. This line generally runs straight from the head toward the tail, in some species extending over part of the caudal fin, in others just reaching its base and in still others falling short of it. In other cases the line is interrupted, incomplete, or curved. In some fishes it is nearer the back, in others nearer the belly. A few species have three lateral lines on each side of the body.

The lateral line is formed of a row of perforated scales, which in some species are the only scales on the body. The perforation is often branched at its outer end. All the perforations communicate with a mucous passage called the lateral canal, which in most cases extends through the head and the long eye socket, sending one branch to the eyelid and another to the lower jaw. The system of lateral canals is especially well developed in the cod and haddock and in deep-sea fishes in general. The system is represented by a series of shallow pouches, opening outwardly, in the lampreys, hag-fishes and sturgeons; and by somewhat deeper pouches of tubular form in the rays, sharks and chimeras. That is to say, the system is well developed in the bony fishes and comparatively rudimentary in the cartilaginous fishes, which stand lower in the scale of evolution.

As the canals are often filled with mucus their function was formerly supposed to be the secretion of mucus for the lubrication of the body and its protection against penetration by water. But the mucus which covers the body is secreted chiefly by the epidermis and the numerous glands of the skin, and the lateral lines and canals were recognized as peculiar organs of sense more than fifty years ago by Leydig, who discovered the lateral nerve, a nerve trunk which runs from the middle brain along the lateral line on each side and sends through each perforated scale a branch which terminates in a little prominence in the lateral line. These prominences are covered by a true sensory epithelium composed of short pyriform cells which terminate in fine bristles. In 1861 Schultze discovered the same organs in the aquatic larvæ of amphibia and inferred that they served for the perception of the relative motion of the body and the surrounding water. Lee regarded them as directional organs, analogous to the labyrinth of the ear, Parker as organs for the perception of slight shocks and vibrations in the water, and Richard as regulators of the evolution of gas in the swim bladder. Yet as late as 1886 Guenther maintained that the function of the lateral organs is the secretion of mucus.

The difficulty of forming a clear idea of the nature of the lateral organs is increased by the absence of such organs from the bodies of man and the higher vertebrates. The problem has been solved, however, by Prof. Hofer's recent experiments on various fishes. The pike was selected as the principal subject of experiment because this fish, if not disturbed, remains perfectly quiet except for a slow movement of the lower jaw, but reacts to light, to slight shocks and vibrations of the water in definite and characteristic ways. A very slight stimulus causes only a spreading and a lateral deviation of five or six rays of the dorsal fin, a stronger and longer stimulus causes the back part of the fin to flap like the sail of a vessel coming up into the wind, and a still stronger stimulus causes all the fins to open, ready for swimming.

If a fine jet of water is directed toward the side of a pike from a point about three inches away and under water, the fish instantly shows by the reaction of its dorsal fin that it perceives the jet, although this does not actually touch the body, and has the same temperature as the water of the aquarium. If the jet is applied for only a second the excitement of the fish subsides in a couple of minutes, but if the jet is continued the excitement increases, all the fins move and the fish turns to face the jet. Fishes "standing" in running water always have their heads pointing upstream.

If the lateral organs are paralyzed by severing the lateral nerves in the gill cavity no reaction follows the application of a jet rapid enough to cause pitting of the flesh, unless the mechanical force of the jet is sufficient to disturb the equilibrium of the body. If the nerve is cut in such a manner as to paralyze only part of the lateral organs on either side, only the region affected becomes entirely insensitive to currents of water, although the sensitiveness of the other regions is somewhat diminished.

These experiments of Hofer, which were repeated on a great many fishes, lead to the conclusion that the perception of water currents is the chief function of the lateral organs. The fish, being thus informed of the motion of the water, is enabled to select waters favorable to the development of its species. Hence the lateral organs regulate the geographical distribution of fishes among various depths of still and moving waters, though the distribution is affected also by food supply, and the temperature and aeration of the water. The lateral organs enable migratory fishes to find the mouths of streams and their tributaries until they reach their spawning grounds in small brooks.

Schultze, who in 1861 inferred the function of the lateral organs from their anatomical structure, thought that these organs also inform the fish whether it is resting in still water or being borne along by a current. But if a vessel of water containing a pike is moved rapidly the fish becomes greatly excited whether its lateral nerves are intact or severed. Hence the fish is informed of the displacement of its body not by the lateral organs, but by some other organs, probably the otoliths or earstones.

Great changes of pressure also have the same effect on fishes, whether the lateral nerves are cut or not. No reaction occurs unless the change of pressure is great and lasting enough to affect the distention of the swim bladder and, through this, the pressure on the internal organs. The lateral organs give no information concerning the magnitude and variation of hydrostatic pressure, nor do they feel the contact of solid bodies. Indeed, the entire surface of the body is entirely destitute of tactile organs. A fish never reacts to mechanical pressure unless this is sufficient to cause internal pain. The interior of the mouth and the gills, however, have very sensitive tactile organs.

If fishes swimming freely in clear water are closely observed it will be seen that they never strike their heads against stones, roots or other solid objects. Fishes do not even collide with the invisible glass walls of an aquarium, and a blindfolded fish stops and turns aside when its head comes within an inch, more or less, of a solid object held in front of it in the water, stopping farther from a wide than from a narrow obstacle. This experiment proves that the fish is able to feel the reflux from solid objects, including the banks of streams and ponds, which is caused by the rebound of the water which the fish drives before it in swimming. Being thus provided with means of detecting the proximity of solid objects before it actually touches them, a fish has no need of organs of touch. The lateral organs take the place of the feelers and tactile hairs which are so conspicuous, for example, in the bats, yet these lateral organs of fishes are not true organs of touch. The lateral organs may be described as sensory organs adapted to aquatic life, the function of which is to give timely warning of every movement of the surrounding water.

If the pike and other predatory fishes are regarded in the light of these facts, their long, slender bodies are seen to be admirably adapted, not only for rapid motion, but also for the reduction of the wave of displacement to a minimum. The effect of this would be to enable the hunter to come close to the prey without giving warning of his approach, if the broad sides of the prey were not amply provided with lateral organs which betray the slightest motion of the water.—Translated from Prometheus.

BELGIAN PNEUMONIA TREATMENT.

Consul-General Henry W. Diederich, writing from Antwerp, gives the following account of another step for the alleviation of pneumonia:

The increasing therapeutic use of serum of animals immunizd by bacteria and bacterial products is one of the most remarkable characteristics of modern medicine. In the treatment of pneumonia, or inflammation of the lung tissue, the results obtained with serum treatment, though they have fallen short of the brilliant results obtained by the prompt use of diphtheria antitoxic serum, have been very encouraging.

There are various preparations in use in this country, in Germany and Switzerland, but they must be applied in rather large quantities and in oft-repeated doses. In cases of moderate severity not less than 50 grains and, in severe cases, 100 grains, and even more must be given, thus injecting at least four to five times the initial dose. To overcome this difficulty Dr. Leon Bertrand, a noted bacteriologist of Belgium, has set himself to the task of preparing a serum that may be applied less frequently, in smaller doses, and with more beneficial results.

In a paper recently read before the Medical Society of Antwerp this scientist claims to have been successful, and he is now preparing a work making known the details of this new serum cure of pneumonia, which is a bactericidal, not an antitoxic agent. It is to be hoped that future results will bear out the good hopes which he now entertains of it.

THE ARMS OF THE VENUS OF MILO.

THE MYSTERY OF A GREAT STATUE.

BY DR. ARTHUR STIEHLER.

MYSTERY enshrouds a number of the most famous works of art and literature. The authorship of some of the Shakespeare dramas is still in doubt, and modern criticism has replaced Homer by a number of lesser bards. The origin of the Nibelungenlied is an unsolvable enigma, and darkness broods over Hindu, Chinese, and Babylonian literature, and even the Bible. Similar examples are found in the field of art. Even ancient critics were unable to decide whether the famous Niobe group was carved by Skopas or by Praxiteles, and modern critics can do no better, as the original statue has perished and only copies remain. In regard to the Venus of Milo, probably the most famous and generally deemed the most beautiful sculptured female figure in existence, our knowledge is still more imperfect. Not only is the name of the sculptor unknown, but it is not certain that the statue is a representation of Venus. The position of the lost arms has formed the subject of widely differing conjectures, which are illustrated by the restorations shown in the accompanying photographs.

To a modern antiquarian familiar with the minute detail with which every discovery of even a fragment of an ancient work of art is now recorded and published, it appears almost incredible that although this statue, the value and wonderful beauty of which must have impressed every observer, was exhumed in 1820, the first earnest inquiry into its origin was made in 1847 and published in 1877.

This noble statue derives its name from the island on which it was found. Milo, or Melos, is the most westerly of the Cyclades group in the Ægean Sea. In very ancient times it was celebrated for the production of oil and fruit and was the seat of an advanced culture, but it was almost depopulated by the Athenians in 416 B. C. in revenge for the neutral stand taken by the inhabitants in the Peloponnesian war. The island contains many ancient tombs and subterranean vaults which have yielded numerous vases and trinkets and a fine head of Asklepios or Æsculapius, which is now in the British Museum. The famous Venus is in the Louvre in Paris.

The age of the statue has been pretty definitely fixed by modern critics. In the earliest period of Greek art goddesses were never represented unclad. Hence the semi-nude Venus of Milo must be of later date, but it cannot have been produced in the latest period of decadence, in which majestic beauty and seriousness of conception had become obsolete. The statue was probably produced in the second century B. C. and is therefore nearly contemporaneous with the Borghese Gladiator, the Laokoon, and the colossal group of the Farnese Bull.

If Dussault's account of the discovery of the statue could be accepted, both the date and the meaning of the work could be determined with accuracy, but the story has not been generally accepted, as is illustrated by the great diversity in the reconstructions of the missing arms. In 1847 the architect Dussault wrote a description of the exhumation of the statue,

FIG. 1.—THE VENUS OF MILO IN ITS PRESENT CONDITION.

and quoted a report of the French consul, substantially in the following terms: "In the year 1820 a farmer named Gorgos, while working in his pistachio field, discovered a deep hole in the ground. Peering in, he saw, he asserts, white, ghostlike shapes. He fled in terror, and appealed to me, as a representative of the government, to exorcise the ghosts. We dug and found a rectangular vault which, with the surrounding earth, had slipped a little way down the bank. In this cavity we discovered several Hermes busts and the masterpiece of Greek art. The statue stood on a pedestal thirty inches high, and the arms lay at its feet. One arm was extended, and the hand appeared as if it had held the garment; the other arm was bent, and the hand grasped an apple."

The arms here described have vanished, and the same writer thus narrates their fate: "A monk, wishing to regain the favor of the governor, which he had lost, determined to present the statue to the official. He paid the farmer a large sum of money for the figure, and had it conveyed to a sailing vessel, but when he was about to sail a French ship, which had been sent for the purpose of carrying off the statue to Paris as a present to Louis XVIII., appeared in the harbor. A conflict ensued. The statue changed owners several times, but finally remained in the possession of the French. In the course of the battle the arms disappeared, and no trace of them has ever been found."

A glance at the accompanying photographs of the mutilated figure and its various restorations will aid in forming an estimate of the amount of truth in these stories, which were not published until twenty-seven years had elapsed since the discovery of the statue and have not been corroborated by any expert testimony. A study of the statue leads to the following conclusions: The facial expression, though beautiful, is grave. The elevation of the left shoulder proves that the left arm was raised, while the drooping right shoulder indicates that the right arm was outstretched. The great prominence of the right hip and the bending of the left knee must find their explanation in the general idea of the whole work, concerning which, unfortunately, we are in ignorance. The garment, if draped without support about a living model in the way it appears in the mutilated statue, would instantly slip down over the hips and fall to the ground.

In the first restoration (Fig. 2) the modern sculptor has represented Venus or Aphrodite immediately after she has received the apple, the prize of beauty, from the hand of the umpire Paris. Dussault's story is faithfully followed. The right hand supports the garment, and the left hand, holding the apple, rests on a pillar, the introduction of which is justified by traces of the insertion of a peg in the pedestal. But the severe expression of the countenance is not accounted for. A Greek artist of that period would not have given so grave a mien to the recipient of the prize of beauty.

The second reconstruction (Fig. 3) also follows Dussault's account, and even introduces one of the Hermes busts which he mentions. This combination of two art forms so different as a finished statue and a Hermes is hardly legitimate. Furthermore, no reason for the raising of the left arm is apparent, and the severity of the facial expression still remains unexplained.

The next restoration (Fig. 4) departs from the Dussault story, and puts a laurel wreath in each hand of the goddess, thus depriving the garment of its needed support and still failing to account for the severity of mien.

Another reconstructed Venus (Fig. 5) holds an apple in her left hand and a bird in her right. This arrangement of the arms and hands is open to both of the objections mentioned above and is also entirely incompatible with the positions of the hips, knees, and shoulders. The restored statue falls into the art cate-

FIG. 2.—THE STATUE RESTORED IN ACCORDANCE WITH THE MYTH OF PARIS AND DUSSAULT'S DESCRIPTION.

FIG. 3.—A RESTORATION INTRODUCING A HERMES WHICH WAS FOUND WITH THE STATUE.

FIG. 4.—THE VENUS TRANSFORMED INTO A GODDESS OF VICTORY.

gory known as "genre," and bears no resemblance to an antique work.

Another restoration (Fig. 6) shows Venus at her toilet, arranging her hair with her left hand and holding a mirror in her right. This is evidently of Parisian origin. The coquettish attitude of the hands contrasts absurdly with the heaviness of the posture of the hips and the gravity of the facial expression. No Greek sculptor could have been guilty of such a composition.

Still another restoration (Fig. 7) shows the goddess writing on the shield of Mars. The artist obtained this suggestion from another antique statue, known as the Aphrodite of Capua and believed to be a Roman copy of a statue by Skopas, which is now lost. In this reconstruction the striking position of the right hip and the left knee is very sucessfully explained by the weight of the great shield, and the general effect of the composition is excellent. The nudity of the upper part of the figure, however, is not accounted for.

This defect can be remedied by a slight modification, which has been suggested by Prof. A. Lehnert of Leipzig. In Lehnert's drawing (Fig. 8) the right arm is extended and the right hand grasps the lower edge of the shield. The goddess is supposed to be gazing at the reflection of her beauty in the polished metal.

But even this suggested restoration does not solve the problem beyond question, and there is good reason to believe that it can never be solved satisfactorily, for the figure is not harmoniously developed from every point of view. It has been suggested that the ancient sculptor copied the facial expression and the position of the hips and the drapery from an Aphrodite by Skopas, of which we have no knowledge, but altered the position of the arms and put in the right hand an apple, the symbol of the city of Melos. According to this theory, the famous statue in the Louvre is not a Venus, but a Tyche, or patron goddess of a city, for such deities were at first represented without the crown of masonry which they wore at a later period. But this is only a theory, though a very plausible one.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Reclams Universum.

FIG. 5.—VENUS WITH AN APPLE AND A DOVE.

FIG. 6.—VENUS AT HER TOILET.

FIG. 7.—VENUS WRITING ON THE SHIELD OF MARS.

THE UNITY OF LIFE—RESPIRATION IN PLANTS AND SYNTHETIC ASSIMILATION IN ANIMALS.

By DR. LUDWIG REINHARDT.

DEFINITE and infallible marks of discrimination between the lowest animals and the lowest plants have long been sought, but the increase of knowledge has engendered and continually strengthened the conviction that no such marks exist. Hence the lowest organisms, which exhibit both animal and vegetable character, have been classified under the neutral name of *Protista*, "the first created."

The fact that animals and plants of the lowest order of development are dependent upon each other for their existence clearly indicates that both have been developed from the same living albuminoid substance of yet unknown constitution, which is known as protoplasm. In the course of time the protoplasm of each kind of organism has become differentiated by acquiring properties appropriate to the conditions of that organism's life. In the words of Matschie, every animal—and, we may add, every plant—is a function of its habit.

Every living thing consumes oxygen and gives off products of oxidation, for the vital process is a sort of combination. But, in order to obtain fuel for combustion, the earliest organisms must have possessed also the power of deoxidation. This faculty is commonly known as assimilation and defined as the ability to absorb carbon dioxide, decompose it, and use its carbon in building up the organic substance of the body. In this process part of the oxygen of the carbon dioxide is similarly utilized, particularly in the formation of carbohydrates, while the remainder is either employed in processes of oxidation or expelled from the body.

In the course of development and differentiation of

FIG. 8.—VENUS USING THE SHIELD OF MARS AS A MIRROR.

Drawn by Prof. A. Lehnert.

organisms a division of labor has been brought about, deoxidation and assimilation being performed almost exclusively by certain organisms, the plants, and oxidation by other organisms, the animals, which, obtaining their food or fuel from plants, almost completely lost the faculty of assimilation at a very early stage of their development.

Hence the distinction between plants and animals has been formulated by saying that deoxidation, assimilation and synthesis of organic matter preponderate in the former, oxidation, analysis and decomposition in the latter. Plants produce albuminoids, carbohydrates and fats, which animals consume. Plants reduce carbon dioxide, water and nitrates, with evolution of oxygen, while animals produce those compounds by the oxidation or combustion of more complex substances, and absorb oxygen for this combustion. Hence plants, in general, absorb heat or convert it into potential energy, and are motionless, because they derive their food from the air, water and soil, while animals evolve heat and move about in search of food. Their energy of motion, as well as their animal heat, is produced by the combustion of their food, and this is obtained, directly or indirectly, from plants which, in turn, feed upon the carbon dioxide and other products of the animal life process.

But these distinctions are only relative. Animals occasionally exhibit the power of synthesis and all plants consume oxygen and generate heat, sometimes in great quantity. The flowers of many plants are much warmer than the surrounding air. Examples of this excess of temperature are: *Gentiana acaulis* 4, male pumpkin blossoms 7 to 9, *Aconitum napelles* 20, *Campanula barbata* 30, *Colocasia* 40, *Arum cordifolium* 63 to 70, *Arum italicum* 70 to 79 deg. Fah.

Only those plants which contain chlorophyl, or leaf green, are able to lead an independent life, that is, to employ the energy of the sun in the synthesis of starch, the source from which other organic compounds are derived. Animals and plants which contain no chlorophyl, such as fungi, feed upon green plants. Hence the frequent occurrence of symbiosis, or life partnership between green plants and other plants or animals. Jelly fishes and worms harbor in their transparent bodies vast numbers of unicellular algae, which under the influence of sunlight deoxidize and assimilate the carbon dioxide excreted by their hosts and thus supply the latter with food. Algae and fungi form similar associations for mutual benefit, which are known as lichens, and were formerly regarded as a distinct order of plants.

Until lately it was believed that no animal contained chlorophyl not derived from plants, and that all green animals owed their color to algae associated with them in symbiosis, but Engelmann has shown that animals can produce chlorophyl identical with that of plants. Cellulose, another substance long regarded as exclusively vegetable, also occurs in certain animals, especially the tunicata, ascidian mollusks, or sea squirts, of whose leathery envelopes it forms the chief structural element. Chitin, which serves a similar purpose in the wing cases of insects and elsewhere in the animal world, differs from cellulose only by the addition of one amido group, NH_2.

Albumen, casein and fibrin, which occur in almost all animals, are found also in many plants. Guanin, allantoin and other substances closely related to the urea of animals have also been extracted from plants. Animals digest albuminoids with the aid of secretions which contain hydrochloric acid, and pepsin and other ferments. In the same manner hydrochloric acid and pepsin are secreted and albumen is digested by numerous "carnivorous" plants (sun dew, pitcher plant, etc.). In short, every test by which animals and plants can be distinguished has proved fallacious.

It has recently been discovered that assimilation is not wholly dependent on the presence of chlorophyl, and that it occurs regularly in certain animal forms destitute of chlorophyl. The Countess von Linden, who has been studying the larvæ and pupæ of butterflies for the past ten years, has proved* that these larvæ and pupæ when surrounded by an atmosphere rich in carbon dioxide, absorb carbon dioxide, use its carbon in the formation of organic compounds and evolve oxygen, under the influence of sunlight. The pupæ also absorbed and utilized nitrogen, hydrogen and oxygen, so that some of them increased con-

* Die Assimilationsfähigkeit bei Puppen und Raupen von Schmetterlingen, Archiv für Anatomie und Physiologie, 1906.

siderably in weight during the period of pupation, although they took no food and lost some of their substance by respiration.

In many pupæ, as in most plants, the volume of oxygen evolved in the process of assimilation was found approximately equal to the volume of carbon dioxide absorbed, but the pupæ of one species evolved a much larger proportion of oxygen. The same anomaly is observed in cacti and other thick-leaved plants, where it is due to the decomposition by sunlight of organic acids formed at night. The production of an excess of oxygen by certain pupæ must be due to the same cause, or to a rapid conversion of carbohydrates into fat, with elimination of oxygen.

In plants, pupæ and larvæ alike, assimilation is performed chiefly by day, and respiration by night, and red light is more potent than blue light to promote assimilation, while the more refrangible and shorter waves of blue light increase the activity of respiration in pupæ. Accordingly, we find pupæ invested with coverings which transmit chiefly red light.

The temperature of the air strongly affects these phenomena. A very high temperature increases respiration so greatly that the phenomena of assimilation are marked. Countess von Linden, having exposed some pupæ to direct sunshine for several hours in order to obtain especially favorable conditions for assimilation, was surprised to note an abundant evolution of carbon dioxide and a slight absorption of oxygen.

Kreusler, in 1876, had a similar experience with plants. In both cases temperatures between 25 and 62 deg. F. were found most suitable for the study of assimilation, though this faculty attains its maximum at a higher temperature (61 to 77 deg. F.), and is not destroyed by cooling below the freezing point.

The proportion of carbon dioxide in the atmosphere is another important factor in assimilation. In the larvæ of butterflies respiration, which is apt to prevail over assimilation because of the animal's activity, is checked by a high percentage of carbon dioxide, so that the assimilation becomes apparent. In pupæ, as in nettle plants, on the contrary, slight differences in the percentage of carbon dioxide had no appreciable effect.

The most favorable season for the study of assimilation in pupæ is spring, which is also the season of most rapid assimilation and growth in plants. Young pupæ are better objects of study than old ones, in which respiration is gradually increased until in the final stage it completely masks assimilation. The humidity of the air is also of importance, as pupæ assimilate more energetically in a moist atmosphere, from which they probably absorb water as well as gases.

Similar results are observed in plants, so that it appears that assimilation is carried on in the same way and influenced by the same conditions in plants and in assimilating animals. In both the chief factor of assimilation is light. Assimilation is most clearly perceptible in the least active animals, while very active animals, like plants in the flowering season, show an increased production of carbon dioxide and consumption of oxygen. Hence, elevation of temperature and every other condition that stimulates the animal's activity tend to mask the process of assimilation.

The assimilation of nitrogen is less affected than that of carbon dioxide by external influences, and is determined mainly by the needs of the organism. Countess von Linden observed an absorption of nitrogen in almost all her experiments with pupæ, but in the experiments with larvæ absorption alternated with evolution of nitrogen. In cases in which the absorption was regular it was greater in the daytime than at night. The same behavior was observed in plants. Countess von Linden's discovery of the regular absorption of nitrogen by the nettle is especially noteworthy, because most physiological botanists deny the ability of plants to assimilate atmospheric nitrogen without the aid of bacteria. The results with pupæ are less surprising, as Regnault and Reiset had already proved that many animals when fasting take up nitrogen from the air.

Countess von Linden observed a considerable increase in size and the appearance of a red pigment in the epidermis of pupæ as results of the assimilation of carbon dioxide and nitrogen. The absolute weight of pupæ exposed to an atmosphere rich in carbon dioxide steadily increased until the gain amounted to one-fourth of the initial weight. This result is the more remarkable because a loss in weight occurs during pupation in normal conditions. The specific gravity first diminished, then increased. In all cases the specific gravity was higher at the end of the experiment than it was in the beginning, and the pupæ absorbed water from the atmosphere, in addition to forming new organic matter, the chemical nature of which could not be determined.

Pupæ examined with a microscope after treatment with carbon dioxide showed a coalescence of oil globules which indicated a formation of fat, but carbohydrates may have been formed first, and subsequently converted into fat. It is still more difficult to trace the history of the absorbed nitrogen, but the final result must be the formation of albuminoids which are used in the growth of the body.

Dr. von Linden surmises that the faculty of assimilation possessed by the pupæ and larvæ of butterflies resides in their epithelial pigments, which are analogous to the chlorophyl of plants. Possibly the coloring matter of the blood may contribute largely to the result. It appears certain, at least, that the pigments are concerned in assimilation, for they are increased in quantity in the process of assimilation. Experiments with the green larvæ of *Botys urticata* make it probable that the blood pigment of this species is the agent of its great power of assimilation.

Are we justified in assuming that assimilation occurs in the pupæ of butterflies under normal conditions? Kellner has shown that the silk worm loses one-half its total weight and one-third its dry weight in the process of pupation, and that the solid substance thus consumed consists chiefly of carbohydrates, only one-seventh of the fat and a still smaller proportion of albuminoids being destroyed.

Farkas obtained similar results for the pupæ of the silk worm, though he found that both the incubating egg and the fasting larvæ live mainly at the expense of their fat. It is possible, however, that the pupæ consume more fat than these results indicate, and that the loss is made good by assimilation or by the conversion of carbohydrates into fat.

Every silk worm grower knows the importance of maintaining a moist atmosphere about pupæ during the winter. Pupæ kept in dry air either die or emerge prematurely. But, unless the water absorbed during the pupal stage serves as food, a dry atmosphere should be favorable to the prolongation of that stage by reducing the activity of the vital process and the consequent waste of tissue to a minimum. Hence, it appears probable that the pupæ use in the formation of organic compounds the water which they absorb from the air.

Only under two conditions is it conceivable that dryness should, like heat, accelerate metabolism. The pupæ must assimilate carbon dioxide, and the moment of emergence must be determined by the exhaustion of the supply of food. This exhaustion is accelerated by heat which increases metabolism and by dryness which diminishes the supply of nutriment obtainable from the atmosphere. In both cases the result is either death or premature emergence from the cocoon. Evidence in support of this view is given by Pictet's discovery that malnutrition of the larvæ also shortens the period of pupation.

The fact that the pupæ of many butterflies, especially of those that fly by day, require light, is an additional indication of the possession of the assimilative faculty by pupæ.

Light and moisture are also required for the growth of assimilative plants. Even the thickest pupa skins, those of the sphinx moths, offer little impediment to red light. The pupal stage of the death's head moth and many others is passed underground in darkness, but Dr. von Linden found that some pupæ of day-flying butterflies and some nettle plants absorbed and decomposed carbon dioxide in absolute darkness, and Hüppe has proved that the nitrifying bacteria have the same property.

Hence, pupæ, deprived of the energy of sunlight, may use some of their energy of combustion or respiration in the re-assimilation of a portion of the exhaled carbon dioxide. This would be an example of metabolic economy unique in the animal kingdom. On this assumption the moist air of the ground, laden with carbon dioxide, would be the best possible atmosphere for pupation. The pupal life of a majority of insect species is passed underground.

Regnard has shown that the air inclosed in silk-worm cocoons contains 2 per cent of carbon, and Kellner found that poorly nourished pupæ, unable to make closed cocoons, lost one-third to one-half of their dry substance during the metamorphosis. Hence, Countess von Linden concludes that pupæ normally re-assimilate part of their exhaled carbon dioxide. While this economy in metabolism can hardly produce actual increase in weight it may suffice to explain the prolongation of the life of some pupæ to seven or eight years.

The experiments on the respiration of pupæ in atmospheric air did not disprove the possibility of assimilation in normal conditions. For example, it was found that the pupæ evolved much more carbon dioxide at night than in daylight. This is what we should expect to find if assimilation occurred in addition to respiration during the day, as it does in plants. Dr. von Linden has, furthermore, obtained direct proof of the evolution of oxygen, and the increase of that evolution in daylight, by butterfly pupæ and by the green larvæ of the moth *Botys urticata*.

Hence, it appears almost certain that butterfly larvæ in normal conditions have some power of assimilation which they use, especially in prolonged pupal life, in replacing part of the matter lost by oxidation.

This power of assimilation, identical with that of plants, will probably be found widely distributed in the animal kingdom. Even now we can trace this faculty up from unicellular animals to insects and crustaceans, for some crabs absorb carbon dioxide, though only for the formation of the carbonates of their shells. And the increase in weight of snails during hibernation, observed by Gredler, is probably due to re-assimilation of carbon dioxide produced by oxidation of tissue. The increase in weight of hibernating marmots has been shown by Dubois to be due to enrichment of the blood and tissue with carbon dioxide. A similar increase in weight has been observed in fasting animals and in one human faster.

All this indicates that carbon dioxide plays an important part in animal, as in vegetable, metabolism. The importance of its accumulation in the body for the production of sleep, hibernation and the quiescence of pupæ has been proved by numerous French investigators, and Dr. von Linden's researches show how it can be assimilated as food for the fasting organism.

In higher animals the observation of assimilation is made difficult by the activity of respiration, due to the activity of life. The preponderance of respiration over assimilation is the character which distinguishes animals from plants and which led to the view that only animals breathe and only plants assimilate.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Prometheus.

EFFECT OF LOW TEMPERATURE ON BACTERIA IN ICE.*

By JOHN C. SPARKS.

MY aim in this paper is to set forth with as little confusing technical terms and phrases as possible, the results and significance of a biological study of the effect of continued low temperatures on the germ life remaining in ice made from impure water. The tests were made specially in regard to bacteria, such as *Bacillus coli communis*, the intestinal germ; typhoid bacillus; sewage streptococci and the anaerobic spore-forming bacilli of sewage, all of these being pathogenic bacilli that may be found in an impure water. To explain a few of the terms used it must first be understood that any bacteria which do not cause disease are not included in this study. Pathogenic, or disease producing bacilli, that may be present in water and ice, are of considerable interest, and the most characteristic bacilli have been studied. Biology in its broadest sense is the study of the life history of any living organism, and includes the effect of the introduction of lower organisms, such as bacteria, into higher organism, such as the human system, and the study of the lower organisms in regard to their distribution, vitality and the effect of environment on them.

The general plan of the methods used was to take a sample of sewage, introduce a small quantity into an enriching dextrose broth for six hours, and plate a small quantity of the diluted broth on a litmus-lactose-agar plate. The cultures were kept at a temperature of 98.6 deg. F. in an incubator. From the plate characteristic colonies of *Bacilli coli communis*, sewage *streptococci*, and the anaerobic spore-forming bacilli were extracted on the point of a fine needle, diluted in sterile water and replated on separate plates in nutrient agar. The resulting pure cultures were separated in the same way as before, characteristic colonies being removed by a fine needle, into the water of a temperature of 98.6 deg. F., and kept at that temperature twelve hours. The water was then frozen into blocks of ice, and these blocks of ice kept in an insulated vessel in a brine-cooled ice box at a temperature of 28 deg. F. The ice remained hard and suffered no loss from meltage. I obtained a fairly pure culture of the typhus bacilli from the pathological laboratory of a hospital, and re-purified it in the same way by replating it on a nutrient agar, and introduced some of the active bacilli into water and after twelve hours froze the water to ice as with the other specimens.

A sample of the water inoculated with the different characteristic types of bacilli that may be found in contaminated water was examined, and a bacteriological count made by the usual methods, so that a record could be made of the content of bacteria in the water before being frozen. All the bacilli were in an active condition in a high state of vitality.

The tests are divided into four tables. All tests were made under the same conditions and at the same time, so a comparison can be made between the various pathogenic bacilli.

1. *Bacillus Coli Communis.*—This bacillus was first isolated in 1884, and it has been found to be a normal inhabitant of the intestinal tract of man and many other animals, and to occur regularly in their excretions. This bacillus is therefore of highest importance when considering the sanitary value of a water, as it clearly indicates sewage contamination. The organism is a short motile rod showing no spore formation. It is an acid producing bacillus, and re-

* Ice and Refrigeration.

duces nitrates to nitrites. It has distinct pathogenic qualities, and 0.5 cubic centimeter of a 24-hour bouillon culture is usually fatal to guinea pigs when injected subcutaneously. There are fifteen distinct biochemical reactions in which this bacillus differs from the typhus bacilli, so it may be considered in a class by itself.

The water containing a pure culture of this bacillus was examined, and a count made to establish the number of bacilli in the original water. A small portion of the ice was removed for each of the subsequent tests, all the examinations being carried out by uniform and standard methods.

EFFECT OF TEMPERATURE OF 28 DEG. ON B. COLI COMMUNIS.

Condition of Water and Ice.	Number of Bacilli in One Cubic Centimeter.	Reduction in Percentage.
Orignal water	88,400	0
Ice after two days	31,260	64.69
Ice after four days	9,080	89.79
Ice after seven days	4,780	94.60
Ice after two weeks	621	99.298
Ice after three weeks	240	99.728
Ice after four weeks	190	99.785
Ice after five weeks	120	99.865
Ice after six weeks	78	99.9118
Ice after seven weeks	43	99.9514
Ice after eight weeks	19	99.97852
Ice after nine weeks	10	99.98869
Ice after ten weeks	4	99.99568
Ice after twelve weeks	0	Sterile.

The chief point in this table is the quick drop in the first few days, and the comparatively slow elimination of the final bacilli. It is evident that some of these bacilli have a greater resistance than others.

2. *Typhus Bacillus.*—This bacillus has been isolated for some years with accuracy. It is a medium long, very motile rod, and is observed to move with a quick, serpent-like action under the microscope. It is not often isolated in water, but may be obtained in quantities from a blood culture of a typhoid patient, and in much larger quantities in the fæces. The bacilli have a very marked pathogenic action, quickly killing guinea-pigs when injected under the skin. The same procedure was adopted as before, and the following results obtained.

EFFECT OF TEMPERATURE OF 28 DEG. F. ON TYPHUS BACILLI.

Condition of Water and Ice.	Number of Bacilli in One Cubic Centimeter.	Reduction in Percentage.
Original water	310,600	0
Ice after two days	108,410	72.04
Ice after four days	28,640	90.86
Ice after seven days	18,194	94.25
Ice after two weeks	12,268	96.13
Ice after three weeks	2,380	99.35
Ice after four weeks	864	99.749
Ice after five weeks	319	99.898
Ice after six weeks	94	99.964
Ice after seven weeks	31	99.9901
Ice after eight weeks	9	99.99862
Ice after nine weeks	0	Sterile

It will be noticed that the temperature quickly reduced the number present in the ice, and that these bacilli are acted on more quickly than the *B. coli communis*. From the table the largest reduction occurred during the first few days and again between two and three weeks.

I thought it might be possible that different strains of this bacillus, obtained from other sources, might have a greater or less vitality, so I obtained two other strains. The ice containing one was sterile in seven weeks, and the other was sterile in nine weeks and so I consider that the latter figure is the true one.

Sewage Streptococci.—No very systematic investigations have been made of these streptococci. All sewage contains them, and in a nutrient containing dextrose they will overgrow the *B. coli communis*. They occur in pairs, short chains, or irregular groups. They are not motile and have no organ for self-propulsion. They are usually slightly oval in form. They can easily be distinguished from other acid-forming bacteria such as *B. coli communis*, from the fact that the red colonies on litmus-lactose-agar retain their color, and do not change to blue at a later stage of incubation.

EFFECT OF TEMPERATURE OF 28 DEG. F. ON SEWAGE STREPTOCOCCI.

Condition of Water and Ice.	Number of Bacilli in One Cubic Centimeter.	Reduction in Percentage.
Original water	72,500	0
Ice after two days	51,600	28.43
Ice after four days	30,760	57.57
Ice after seven days	26,841	62.98
Ice after two weeks	10,424	85.64
Ice after three weeks	3,100	95.729
Ice after four weeks	941	98.702
Ice after five weeks	208	99.713
Ice after six weeks	174	99.760
Ice after seven weeks	153	99.7890
Ice after eight weeks	89	99.8806
Ice after nine weeks	64	99.91127
Ice after ten weeks	58	99.91959
Ice after twelve weeks	52	99.92966
Ice after fifteen weeks	16	99.97931
Ice after twenty weeks	0	Sterile.

The sewage streptococci were not as sensitive to temperature as the *B. coli communis* or the typhus bacilli, and the reduction during the first few days was much less. These streptococci may vary considerably in general characteristics in different sewage, so I took five other samples of sewage and found the streptococci obtained from them in ice at 28 deg. F. as follows: No. 1, eighteen weeks; No. 2, twenty-three weeks; No. 3, twenty-five weeks; No. 4, sixteen weeks, and No. 5, twenty-two weeks. It is only recently that much attention has been given to these organisms as indications of contamination of water by means of animal waste. Houston, in 1899, showed that in six polluted river waters he found a streptococci in from one-hundredth to one-thousandth of a cubic centimeter of the water examined, and with water which was known to be pure no organisms of this class were isolated from as much as 100 cubic centimeters of water.

Anaerobic Spore-forming Bacilli.—This group of bacilli is very different from the preceding ones in that they are not dependent on atmospheric oxygen, and exist best when not in contact with oxygen. These bacilli were prepared by adding sewage to sterile milk which was placed in a tube and tightly plugged with cotton, and pyrogallic acid placed above, and the tube sealed with a rubber stopper. The milk after incubation for twenty-six hours showed pinkish white masses of coagulated casein, and the whey contained numerous bacilli in the form of stout short rods. These were separated and a new culture made on glucose agar and when added to gelatin produced large oval spores. These bacilli are strongly pathogenic to guinea pigs. Several types of spore-forming bacilli were taken, though most of them were of the *B. sporogenes* type. This bacillus was isolated by Klein in 1898, in the course of an epidemic of diarrhœa at St. Bartholomew's hospital, London, and is found to occur in sewage in numbers varying from 30 to 2,000 per cubic centimeter, and is often absent in large volumes of pure water. The number present in sewage is relatively small, but as they are characteristic of sewage, were included in this test. An examination for this organism in water should be conducted on large samples of the water, about 2,000 cubic centimeters concentrated by filtration, to have much significance.

EFFECT OF TEMPERATURE OF 28 DEG. F. ON ANAEROBIC SPORE-FORMING BACILLI.

Condition of Water and Ice.	Number of Bacilli in One Cubic Centimeter.	Reduction in Percentage.
Original water	1,640	0
Ice after two days	1,280	30.61
Ice after four days	1,020	37.81
Ice after one week	935	42.87
Ice after two weeks	750	54.26
Ice after four weeks	184	88.78
Ice after six weeks	98	99.402
Ice after eight weeks	74	99.5487
Ice after ten weeks	60	99.6342
Ice after fifteen weeks	12	99.9267
Ice after twenty weeks	0	Sterile

The figures obtained were a surprise to me, as they were not at all what I expected. It may be possible that the standard conditions under which the counts were made had some bearing on the result. I made a culture of each sample of the ice taken at the different times on a nutrient plate for forty-eight hours, and took the count at that time. It is possible that some of the spores had their vitality sufficiently impaired to show no growth in that time. The big drop between the second and fourth week is unlike any of the other tests, and the reason for it does not appear very clear. It is evident, however, that temperature has a distinct action on this type of bacilli, and a much greater action than I should have thought possible, as they will flourish under conditions in which the *B. coli communis* and the typhus bacilli cannot exist.

The conclusions that can be drawn from these tests, taken as a whole, are that temperature has a marked effect on the vitality of the pathogenic bacilli, and that all the bacilli are not equally affected, some having greater vitality than others.

The samples of ice, made up to contain the various pathogenic bacilli, had a very much greater content per cubic centimeter than is ever found even in a heavily polluted water, and therefore the percentage of reduction is of greater importance than the numbers contained. I examined about fifty samples of ice last winter, taking the samples myself from different ice fields, and found the average bacterial content to be 220 colonies per cubic centimeter. All of these bacilli require a temperature corresponding to the normal temperature of the human system for their most prolific growth, and as this temperature is 98.6 deg. F. it is seen that a temperature of 28 deg. F. gives a very different condition.

In drawing any conclusions from the above tests, and in trying to find a reason for the results obtained, we must consider the habits of the bacilli in their natural environment, and in ice. The coli communis, typhus, and the spore-forming bacilli are all motile and have the power of moving in a liquid medium in search of their food. The streptococci are not motile, but the movement of the liquid in which they are present brings them new food. In ice the liquid is congealed to a mass in which movement is not possible, and new carbo-nitrogenous food cannot be obtained by the bacilli. This change in environment probably has as much to do with the reduction in the number of the bacilli as the temperature.

I have made a search to find what previous tests have been made along the same lines, and find that there is very little published on the subject. In a paper read by Dr. William H. Park, before the section on Hygiene and Sanitary Science of the American Medical Association, at Atlantic City, June, 1907, he states that he made tests as to the effect of low temperatures on typhoid bacilli, using twenty-one different strains. He goes on to say:

"In these experiments twenty-one different flasks of Croton water were inoculated, each with a different strain of typhoid bacilli. In one a little of the fæces, rich in typhoid, was directly added. The infected water in each flask was then placed in a cold storage room in which the temperature varied from 20 deg. to 28 deg. F. At first tubes were removed and tested twice a week, later once a week. The object of using so many different strains was because it has become evident that some cultures lived longer than others."

LIFE OF TWENTY-ONE STRAINS OF TYPHOID BACILLI IN ICE.

Condition of Water and Ice.	Average Number of Bacilli in Ice.	Percentage B Typhoid Living.
Before freezing	2,560,410	100
Frozen three days	1,089,470	42
Frozen seven days	361,136	14
Frozen fourteen days	203,300	8
Frozen twenty-one days	10,280	0.4
Frozen twenty-eight days	4,240	0.17
Frozen five weeks	2,950	0.1
Frozen seven weeks	2,302	0.09
Frozen nine weeks	127	0.005
Frozen sixteen weeks	107	0.004
Frozen twenty-two weeks	0	0

At the end of five weeks the water infected with six cultures was sterile, at the end of sixteen weeks only four strains remained alive.

No tests were made on the other pathogenic germs contained in sewage by Dr. Park.

Dr. Eugene H. Porter, Commissioner of the Board of Health of New York State, issued a statement in April, 1907, in the daily press, in which he stated:

"The effect of low temperature upon the vitality of bacteria is proportional in a measure to the degree of cold, but of much more importance is the time of exposure. According to our best authorities, we may say in general that bacteria are reduced in number about fifty per cent after exposure to freezing temperatures for a period of one hour; ninety per cent after twenty-four hours; and practically one hundred per cent after exposure from two to three weeks. The few that are not killed after exposure for, say, one month have become so attenuated as to be unable to produce disease."

Dr. W. T. Sedgwick, professor of biology of the Institute of Technology, Boston, states that:

"Many typhoid germs are killed by freezing, and after two weeks' exposure in the ice, upward of ninety-nine per cent die; the remaining germs, while quite hardy, gradually are weakened and eventually die. As a vehicle of disease, ice is plainly far less dangerous to the public health than is either water or milk."

My tests show that a reduction of 99 per cent, or over, was reached in the case of the *B. coli communis* in two weeks after freezing; typhus bacillus three weeks after freezing; sewage streptococci five weeks after freezing; and the anaerobic spore-forming bacilli six weeks after freezing. I have no doubt that this result would have been reached more quickly at a temperature of zero, but I wished to hold my ice at a temperature as nearly to the freezing point as possible without suffering loss from meltage. There was a small loss from evaporation probably, but it would cut no figure.

The chief point to be learned from this series of tests is that ice, even when cut from water which may contain pathogenic bacilli, is utterly incapable of passing on disease if it is stored for some time before being distributed.

Consul-General Robert J. Wynne reports that London's consumption of water was 82,125,249,347 gallons, according to the annual report of the Metropolitan Water Board for the year ending March 31, 1907. A staff of 770 officials, receiving $753,531 in salaries, superintends the work of the board, which is shown by the following totals: Total water supplied, 82,125,249,347 gallons; daily water supply, 225,000,683 gallons; area supplied, 537.4 square miles; population supplied, 6,851,045; daily average per person, 32.84 gallons.

AUTOMATIC CAB-SIGNALING.*

A DISCUSSION OF MODERN RAILWAY SAFETY DEVICES.

BY J. PIGG.

Continued from Supplement No. 1694, page 390.

As already stated, Raven's system of cab signaling is electrical, and it is designed to collect indications by the rubbing of metallic brushes (Fig. 10) carried on the engine over metallic bars (Fig. 15) placed on the line. This method of collection is not essential to the system, since it is capable of being operated equally well without contact, by causing electro-magnets on the line to influence magnets on the engine. This method of collection is not now being put forward.

The system is one which uses visual and audible signals. The visual signals are (1) a small semaphore arm by which the "condition of line" signals are

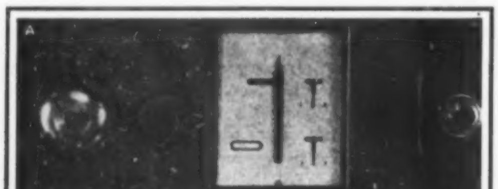


FIG. 8.—"WARNING" AND "ON" INDICATIONS (BELL RINGING).

given, and (2) two small pointers showing 1-2 and 3-4 respectively, which are the "route" indicators. The audible signals, which are of the nature of "call attention" signals, are given by a bell. Besides these indicators, the instrument carried on the engine includes a visual "failure" indicator, by which the condition of the apparatus can be gaged.

Figs. 6, 7, and 8 show several forms in which the indicator on the engine has been made, the circular form being the latest. Fig. 9 shows in diagrammatic form the complete equipment of engine and line circuits, the latter being for a 3-way diverging junction. Fig. 11 is a photograph of the back of the engine indicator with the cover removed to expose the apparatus.

The action of the apparatus is of the simplest possible character, the main principle being the invariable operation of the apparatus at certain points by the natural action of certain parts without the aid of either the signalman or the driver, and the subsequent continuance of the indications resulting from the natural operations until they are stopped or reversed by the action of the signalman.

Considering Fig. 9, and leaving, for the present, consideration of the line of bars out of the center of the space between the running rails, it will be found that the short-circuiting of brushes 1 and 2 on, say bar *A*, causes a current to pass through the main magnet, A^1, by which its armature is raised, putting the semaphore arm to "danger." At the same time the armature closes the circuit of the springs *c*, *d*, diverting the current direct back to the battery after passing through A^1. Hence the armature of the latter will remain attracted to the poles as long as may be necessary for the purposes of the apparatus.

Besides passing through A^1 and the brushes, the initial current passes through the bell relay C^1 during the continuance of the short-circuiting of the brushes 1 and 2; the armature is attracted and breaks the circuit through the spring contact (*e*). This contact forms part of the bell circuit, which itself is connected in shunt across the electro-magnet A^1. Hence when the armature of *A* is raised, the current from the engine battery tends to divide, part passing by A^1 and part by the bell. The connections, however, are such that current only passes to the bell when C^1 is unenergized, and this condition only obtains when the brushes 1 and 2 are not short-circuited. When the brushes are on a metallic bar, say *A*, therefore, the bell is silent, but as soon as they pass off the bars it commences to ring.

In addition to passing through the electromagnets A^1 and C^1, as described, the current to the brush 1

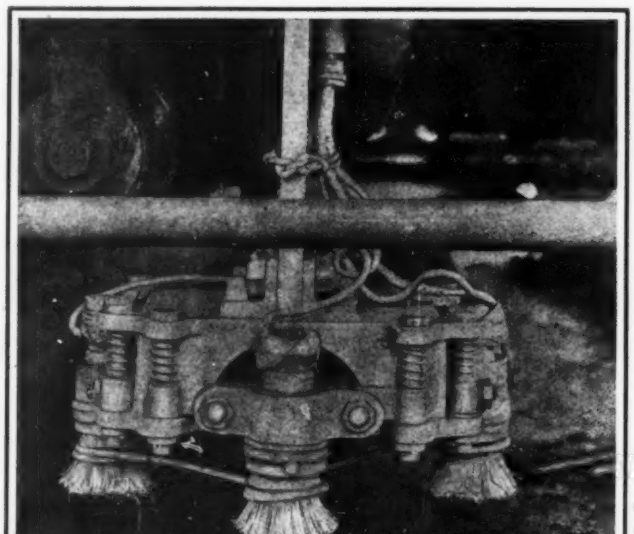


FIG. 10.—THE FOUR STEEL WIRE BRUSHES, SHOWING "FAILURE" INDICATOR CIRCUIT WIRE WRAPPED AROUND THEM.

* Abstracted from an address before the Newcastle Section of the Institution of Electrical Engineers.

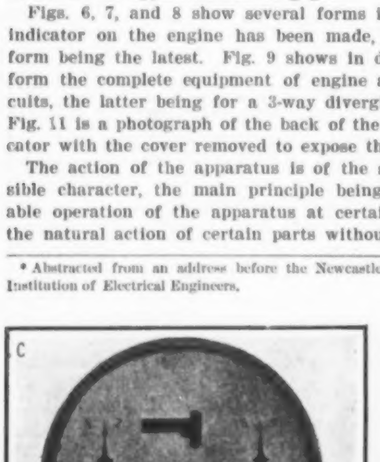


FIG. 6.—THE FAILURE INDICATOR ON THE ENGINE.

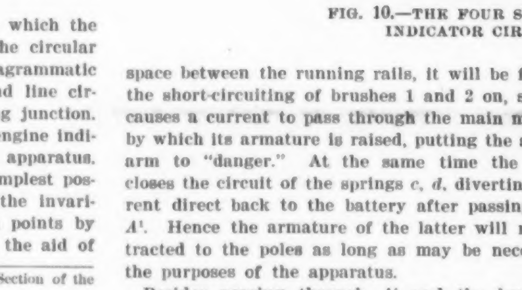


FIG. 7.—"OFF" AND "ROUTE" INDICATIONS.

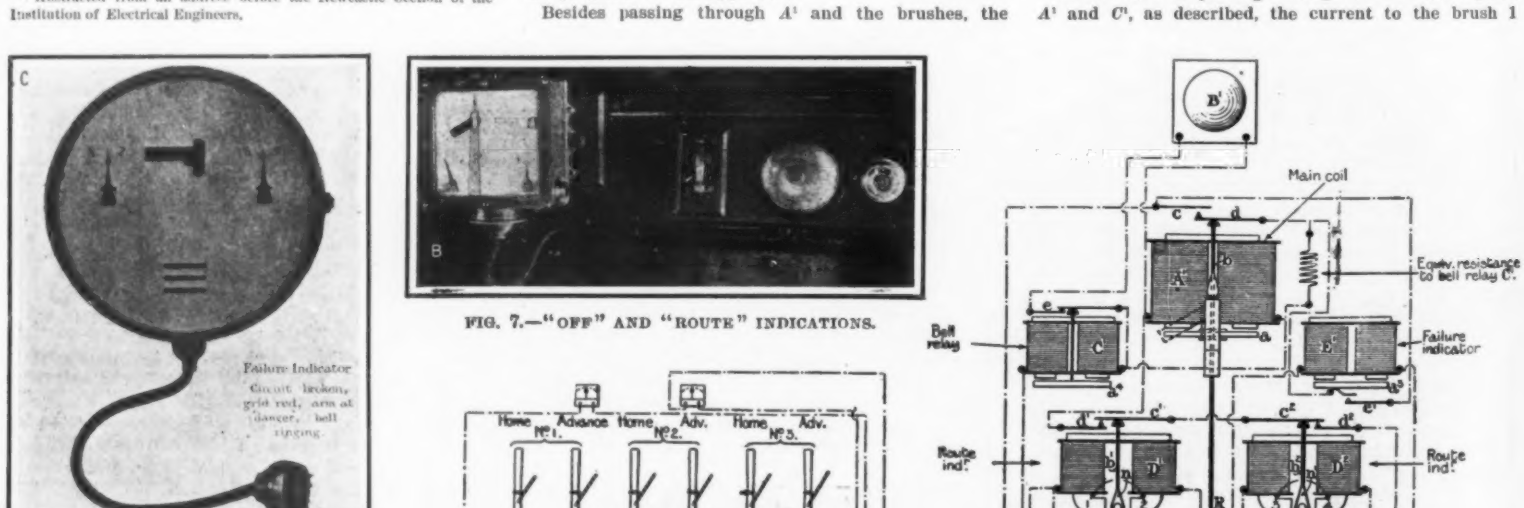


FIG. 9.—DIAGRAM OF ENGINE AND LINE CIRCUITS.

AUTOMATIC CAB-SIGNALING ON LOCOMOTIVES.

passes through the springs c^1 d^1, and c^2 d^2, each pair of which is normally in contact. These springs are opened by the raising of the armatures of D^1 and D^2, respectively. Opening the circuit of either c^1 d^1 or c^2 d^2 obviously releases the armature of A^1, and, as a consequence, stops the ringing of the bell and lowers the semaphore arm.

Currents passing through D^1 are collected from the line by the brush 2, currents passing through D^2 are collected from the line by one or the other of the brushes 3 and 4.

Between the poles of D^1 and D^2 are placed magnetized needles n, n^1, pivoted to turn under the polarity of the poles when the electromagnets are energized. The spindles carry the pointers, shown in Fig. 6. Each spindle also carries a small metal sector, slotted as shown by Figs. 9 and 11, in which rides a small metallic loop, pivoted at the other end. The passage of a current through, say, D^1 deflects the needle to one side, and the loop drops into a recess at the end of the slot, and locks the needle and pointer on the front of the instrument in the deflected position. At the same time this occurs the lifting of the armature of D^1 breaks the contact c^1 d^1, and lowers the semaphore arm, and stops the bell as already stated.

The engine carries, in addition to the apparatus described, two rotary switches, of which further details are shown in Figs. 12 and 13. Each switch consists of a cast-steel wheel free to rotate, the spindle of which carries a two-part commutator, on which bear two springs. The wheel is weighted so as to take up a normal position. In this position the springs bearing on the commutator are insulated from each other, but when the wheel is rotated they are connected through the commutator. The springs are connected with the brushes 1 and 2, respectively, and each rotary switch, when turned from its normal position, connects the brushes in the same way as the latter are connected when on the bar A, or any subsequent bar of those shown in Fig. 9.

The rotary switches 5 and 6 run over fixed bars on the line side of the general form shown on the diagram, and of which more detail is shown by Fig. 14. These bars are fixed in close proximity to the bar A, as shown by Fig. 15. Hence the rotary switches are only actuated at or near the bar A.

(To be concluded.)

SPAIN FEELS THE NEED OF FORESTS.

A SUGGESTION by Spanish manufacturers that Spain plant forests for pulpwood and follow Italy's example by planting quick growing species has been reported to this government by Consul-General Ridgely, of Barcelona. Spain is waking to the necessity of growing her own timber. Nearly all civilized countries are moving in that direction because it is coming to be understood that countries which do not grow their own timber must go without it for a few decades.

It has been customary to cite Spain and China as examples of the distressing results which follow forest destruction. Spain is as large as Pennsylvania, Delaware, Maryland, West Virginia, Virginia, and North Carolina, but its forests have only three-fourths the extent of West Virginia's alone, and much of them are scrub thickets of a very poor kind.

The country's population is believed not to exceed one-third of what it once was, or what it might be again. Much of the denuded land is absolutely barren, with the red rock laid bare where agriculture once flourished. Hills, whose rounded forms indicate they once supported forests, are bald and dry now and without inhabitants. In some localities peasants, with hammers, pulverize rocks and make little patches of soil for gardens.

At the present time Spain's most valuable forest product is cork. The annual cut is 30,000 tons, but the cork forests are going, as other forests went, and for the same reason—want of care. Enterprising Spaniards are just now trying to supply their country with home-made paper, but pulpwood is not to be had except by importing it. The home cut is only 2,500 tons a year—about what a single American pulp company would use in three days.

Foresters say that there is no reason why Spain might not do what France, her next neighbor on the north, has done, cover her barren places with for-

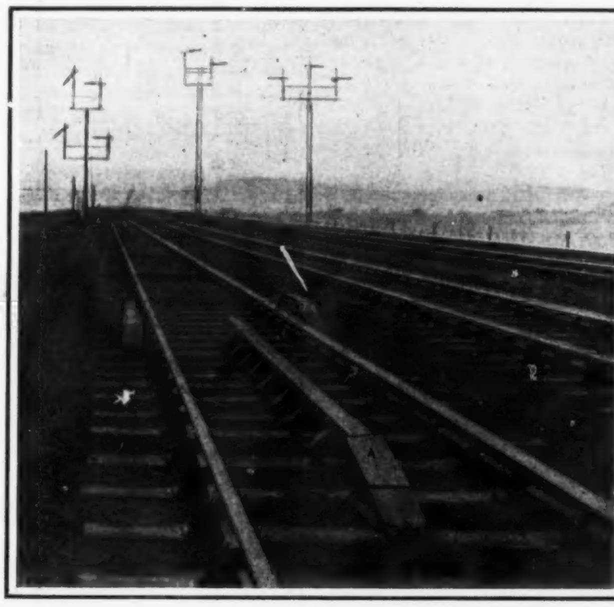


FIG. 15.—BAR A IN CENTER OF TRACK WITH SPRING BARS OUTSIDE TRACK JUST IN ADVANCE. BAR B IN CENTER OF TRACK 600 YARDS BEYOND A. "DISTANT" SIGNALS (IN DUPLICATE) "OFF" FOR ROUTE. LENGTH OF BARS A, B, C, D (SEE FIG. 9) 30 FEET. LENGTH OF BAR E, 60 FEET.

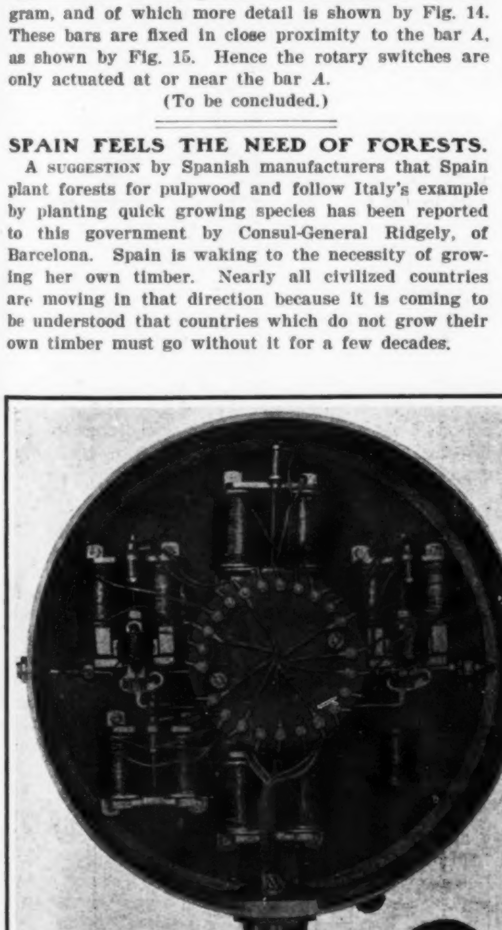


FIG. 11.—BACK OF CIRCULAR TYPE OF INDICATOR WITH COVER REMOVED.

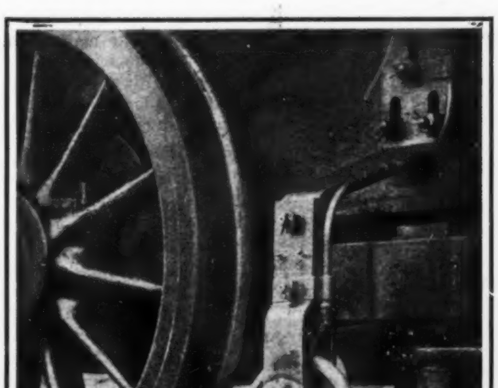


FIG. 12.—ROTARY SWITCH FIXED ON ENGINE BOGIE, SHOWING SERRATED PLATE FOR CONVENIENCE OF ADJUSTMENT.

FIG. 13.—ROTARY SWITCH WITH COVER REMOVED, SHOWING COMMUTATOR AND SPRINGS.

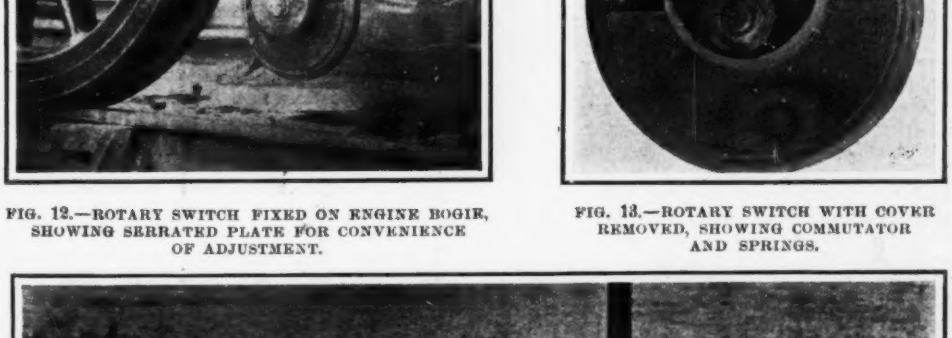


FIG. 14.—SPRING OR YIELDING BARS, WITH RAMPS. LENGTH OF BARS, 6 FEET.

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ests, restore the soil, abate floods, mitigate droughts, provide employment for many, and furnish raw material for manufactories.

ENGINEERING NOTES.

Mr. J. S. Wilson, M.Inst.C.E., and Mr. W. Gore, M.Inst.C.E., have prepared some India-rubber models and apparatus used for the investigation of the distribution of stress in dams. The model, which rests on the top of the trestle, consists of a slab of India-rubber cut to represent the section of a dam, together with its foundation and substratum. The water pressure against the dam is reproduced by plates pulled against the upstream face of the model by cords passing over pulleys and attached to weights. The correct ratio between the density of the fluid represented by that pressure and the density of the masonry (1:2.25) is maintained by suspending a large number of weights from pins passing through the model at uniformly distributed points. To obtain strains large enough to measure, both densities are magnified forty times. Photographs are taken of the model and the system of lines ruled on it, one when unstrained and the other when strained by the various forces. The strains are determined by measuring corresponding lengths and angles on the two photographic negatives by means of the optical projection micrometers which are exhibited. The stresses are calculated from the measured strains by the equations relating them which have been experimentally verified.

Considerable anxiety is now being expressed in France in regard to the reclamation of the Bay of Mont Saint Michel. More than thirty years ago projects were formulated for this purpose, but very little work was done, though some of the estuary on the west of the bay has been reclaimed from the sea. The matter is now again being mooted, and opinions are expressed that if the bay as far seaward as Mont Saint Michel itself is claimed the unique character of the mount will be lost. Unquestionably the expanse of alternate sea and sand has a striking effect, and tends to preserve the unique character of the place. Nor can it be said that the destruction of the peculiar surroundings of the place is required for an important public improvement, for the reclamation of the land is a purely private speculation. On the other hand, some of the solitary charm of Mont Saint Michel has been lost since the making of the narrow embankment on which a road and a tramway have been constructed, so that during many days of the summer the mount is overrun by a crowd of ignorant sightseers, who merely make it the termination of a day's excursion. It would be a great improvement if the restaurant and hotels were removed to the mainland, and the mount and its buildings left in their pristine tranquillity and peace. Visitors could still study the architecture and characteristics of the place, and the islet would be freed from the presence of a number of excursionists whose only interest is to find a restaurant for a *dejeuner*.

In answer to inquiries from the United States, Consul-General Robert P. Skinner, of Marseille, furnishes the following information relative to the effect of wayside trees on French roads: It is proposed to plant trees along the roadsides of New York State in order to keep the moisture in the road and prevent raveling, and the question has been raised whether or not the roots of such trees may spread out underneath the road surface, and eventually create great damage in a severe climate where there are extremes of heat and cold. While French roads are not always bordered with shade trees, they are so very frequently, and my information is that the trees are planted not only for furnishing shade, but in order to protect the roads themselves against the effects of excessive heat and drought. It is believed that the long, dry summer season is much more inimical to roads than severe cold. The chief officer in charge of the public roads in Marseille is of the opinion that, on the whole, New York roads would be benefited if bordered with trees, suggesting, however, that only such should be planted as have vertically descending roots. F. Birot, civil engineer, and former conductor of the bureau of bridges and highways, expresses himself as follows on the subject: In countries where the climate is damp roadside trees are prejudicial to the maintenance of the highways, as they prevent the circulation of the air and the drying of the soil; in most of the southern French regions such plantations are, on the other hand, very useful in dry weather, as they maintain the roadbed in a state of freshness favorable to its conservation. In general, trees should be selected with high spreading branches, such as the poplar, the elm, the ash, and they should be planted generally upon the outer edge of the roadbox and at distances of 10 meters (32.80 feet). Each tree should be placed in a hole 1 meter (3.28 feet) deep and 1½ meters (4.92 feet) square, and should be trimmed to a height of 2½ meters (8.20 feet) above the surface. The earth about newly-planted trees should be loosened in March and November—in March only after the third year—and thereafter until their permanent growth appears assured; small trenches should be directed toward the foot of the tree, in order to secure the benefit of rains. Finally, the tree itself should be trimmed annually during the first ten years.

SCIENCE NOTES.

Railroad companies are constantly looking to furnish amusement for their passengers, as much so as steamship companies. It has not been found practicable to play billiards on a fast train, but the officials of the Burlington road propose to equip their best train with bowling alleys, which they consider will prove an excellent form of amusement and exercise.

Unfortunately it very often happens that those intrusted with the care of priceless and irreplaceable historic buildings and monuments are not able to realize the value of such structures. An instance is furnished by the attitude of the municipal authorities at Rome toward the ancient city walls. Not content with making the opening found necessary for the Trastevere railway, the municipality have destroyed a large portion of the wall on either side of the line in a perfectly ruthless manner. Their latest proposal is that one of the towers of the Porta Salaria should be converted into an elevated water reservoir in connection with an additional water supply scheme. No doubt it is a praiseworthy thing for municipal councils to make every endeavor to reduce the cost of public works, but economy must not be practised at the cost of national monuments, and we are glad to note that a strong protest has been made by the Archæological Commission against the project in question.

According to Lancelot Andrews absolute alcohol prepared by the use of calcined marble has the same density, the same refractive index, and the same critical temperature of solution as that which has been dried by the use of metallic calcium or of magnesium amalgam. The observations of Caismer to the effect that the critical temperature of solution of absolute alcohol in kerosene is the best criterion of the dryness of alcohol is fully confirmed. Absolute alcohol was found to have the following constants:

Density	25°/40°	0.78510	0.00002
Zeiss immersion refractometer..	85°.30	0.02 at 25° H	
Index of refraction..........	1,35941	0.00002	25° H

A table is presented showing the refractive indices by the Zeiss immersion refractometer readings of aqueous alcohols for each per cent of water from 0 to 30. It is shown that aqueous alcohol has a maximum refractive index of 1.363315 0.000010 at 20.7 per cent of water, corresponding to the formula.

What is the effect of motoring upon the human body and health generally? High-speed traveling, it is maintained, disturbs the nervous equilibrium, while other dire ill effects are popularly stated to arise from rapid movement along the highway. But scientific research proves the contrary; and that it tends to cure many disorders which otherwise defy treatment or the palliation of which is only temporary is shown by the investigations of Mons. A. Mouneyrat, who recently read an interesting paper upon the subject before one of the learned societies of France. As a result of his experiences, he finds that motoring improves the skin, acts as a powerful stimulant to the blood, is an excellent means of toning up the blood-circulating system, the nervous system, respiration—in fact, is a course that should be extensively followed by persons suffering from several common complaints, such as anæmia, sleeplessness, loss of appetite, etc. For the purposes of his investigation he embarked upon several motoring tours, lasting on the average over eight days, and covered from sixty to one hundred and twenty-five miles per day, at an average hourly speed of twenty-five miles, in all seasons of the year. The result he found to be a decided increase in the number of red corpuscles in the blood. This augmentation was decidedly striking in character, the number of corpuscles in one anæmic case rising from four million three hundred thousand at the time of starting to five million six hundred thousand corpuscles per cubic millimeter at the end of eight days' motoring; while other results were no less striking, the average increase being approximately 26 per cent. It is noticeable, the investigator points out, that a motor trip exercises the same effects upon the human body as a stay in the mountains at a height of from four thousand to six thousand feet above sea-level, and the effect is as striking upon normal as upon anæmic persons, though naturally in not so notable a degree. Sleep is induced both in neurotic and normal persons, the former, who invariably sleep but little, rapidly becoming normal. That the sport also acts as an appetizer is well known, and the motorist always partakes of his meals in the height of summer, when the tendency is to lose the appetite, with more enjoyment than the ordinary individual.

TRADE NOTES AND FORMULÆ.

Artificial Patina on Brass.—Paint the article with the following preparation: 30 parts by weight of copper dissolved in 60 parts by weight of concentrated nitric acid, 600 parts by weight of vinegar (6 per cent), 11 parts by weight of ammonium chloride, 20 parts by weight of ammonia. In a few days the mixture will be ready for use. Paint it over the articles, allow it to dry, and when dry apply a thin coating of linseed oil with a brush.

Transparent Varnish for Furniture.—The favorite clear varnish for pine-wood furniture, through which the structure of the wood can be seen, is prepared in the following manner: The furniture is first polished while dry with pumice, and then coated with clear, colorless, thin copal varnish. Every coating must be thoroughly dry before a fresh coating is applied. The appearance of the furniture will be much improved if after the first varnishing and drying it is again polished with fine or worn-down sandpaper. If the furniture is to show a tinge of color, linseed oil, to which a little of the desired color is added, should be used for the first coating after the preliminary rubbing down. Only transparent colors, burnt and unburnt sienna, Cassel earth (Vandyke brown), etc., are used for coloring; as these colors dry badly, a considerable quantity of siccative must be added. Another polishing is advisable after drying, followed by coating with colorless copal varnish in the manner described above.

Celery Salt.—We give two recipes for making celery salt, taken from the Zeitschrift des Allg. Österr. Apothekervereins. (I) Cut 1.6 parts of celery root in disks of about one-fifth of an inch in thickness and mix carefully and evenly with 16 parts dry salt, care being taken to avoid crushing or bruising the celery. When the salt has absorbed all the juice of the celery, put it into a dish and keep for half an hour in the stove. Then stir for ten minutes and dry again till the salt is all agglomerated. Then powder and sift the salt and keep in well-closed vessels. (II) Steep 120 parts salt in 7 parts essence of celery. The essence is obtained by macerating 1 part crushed celery seeds in 3 parts concentrated alcohol for seven days and filtering.

Spontaneous Ignition of Various Substances.—According to R. Hauck (Allgemeine Ingenieurzeitung) spontaneous ignition occurs in the following substances at the specified temperatures:

	Deg. C.
Lignite or brown coal, about............	150
Greasy polishing rags, about............	170
Coal, about	200
Wood, about	230
Coke, about	250
Anthracite, about	300

All the above substances, however, will ignite at much lower temperatures if they are exposed to heat for days and weeks. In the case of wood, pasteboard, and cotton it has been proved that a temperature of 120 deg. to 150 deg. C. is fully sufficient to produce spontaneous ignition.

A Practical Plastering for the Interior of Tile Stoves.—A very durable plastering for stoves is recommended by George Zehner in the Kalk, Gips- und Schamotte-zeitung. Take from 25 to 30 per cent (according to its plasticity) of clay and 25 to 30 per cent of annular-kiln ashes. The latter must not be mere dust, but the more solid fragments of stone deposited on the furnace bed. If any slag is available, take equal quantities of slag sand and annular-kiln ashes, 10 per cent rock salt, 15 per cent chamotte powder, and 20 per cent chaff of grain—wheat, corn, or oats; mix thoroughly and make into a thin paste. Then dissolve salt in hot water, taking 1 part of salt to 4 or 5 of water. As soon as the stove walls are freed from dust, moisten them well with the salt water and apply the paste, making the surface smooth, and even immediately afterward with a mason's brush dipped in salt water. If the plastering is renewed every year, there will be a considerable saving in the cost of repairs.

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